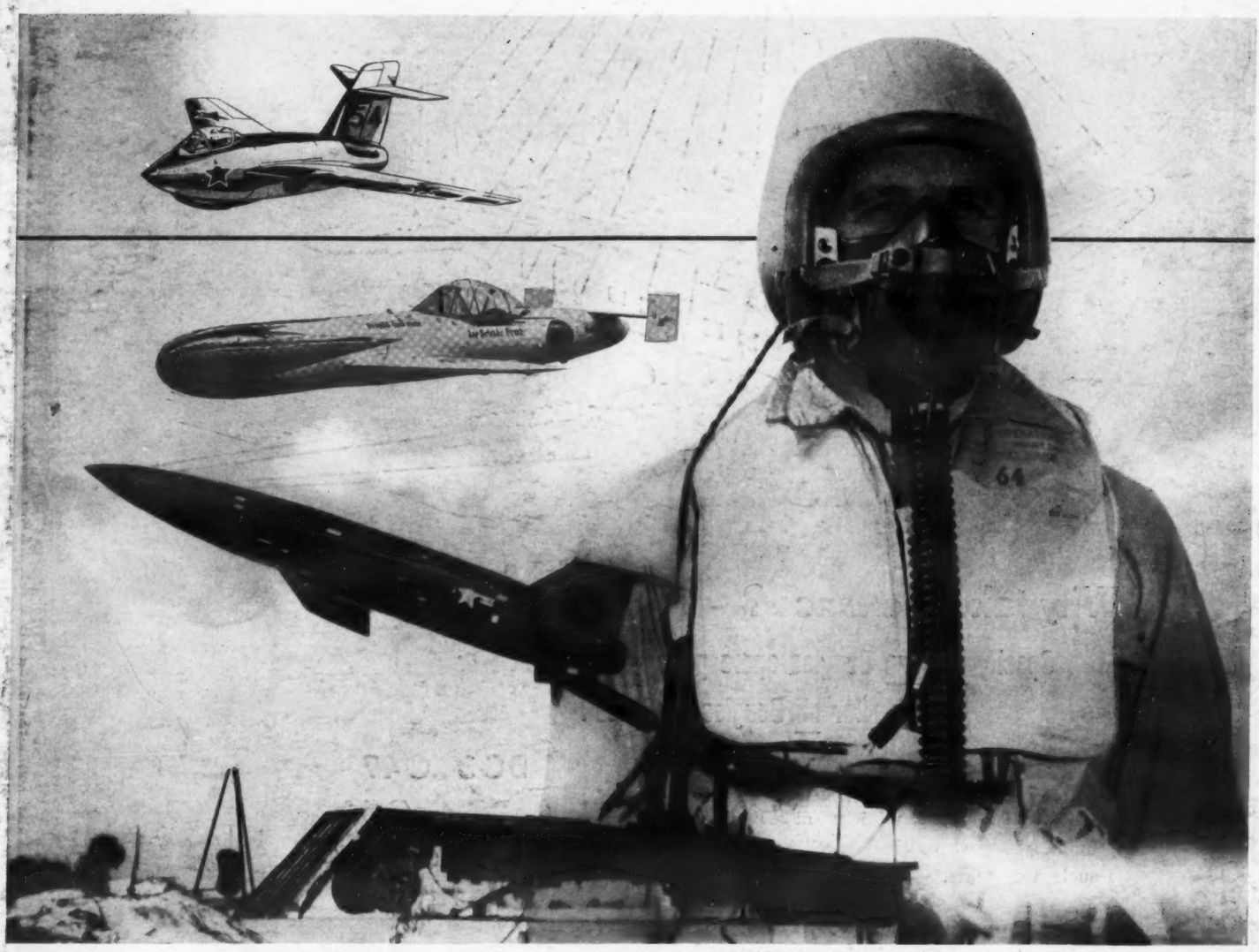
INTERAVIA

REVIEW OF WORLD AVIATION



Price of this issue:

U. S. A.:	80 cents
British Isles:	5 s.
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Short-Life Aircraft

VOLUME VII 7 1952

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Volume VII — No 7 — 1952

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Publishers and Distributors: Interavia S. A. **Proprietors:** Volamecum S. A.

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MILITARY AVIATION AT THE CROSS ROADS:

Costly high-performance aircraft — cheap short-life aircraft — or... unmanned guided missiles?

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Advertising Department, Publishing and Editorial Offices, Subscription Department: Interavia S. A., 6, Corraterie, Geneva. Telephone: 5 42 34 (five lines). Cables and Telegrams: Interavia-Geneva.

Annual Subscriptions: Switzerland, Sw. frs. 28.00; U. S. A. and Canada, U. S. $7.00; Great Britain, £2-6-0d; France, Fr. frs. 2,400; Belgium, Belg. frs. 360.00; Holland, Fl. 31.00; Germany, DM 28.00; Sweden, Kr. 35.00; Norway, Kr. 50.00; Spain, Ptas 275.00; Austria, ö. S. 170. Brazil, 230 Cr$; Uruguay, 23 pesos. All other countries: Sw. frs. 28.00.

Agents and Distributing Offices:

INTERAVIA AUSTRIA:	Morawa & Co., Wollzeile 11, Vienna I.
INTERAVIA BELGIUM:	Office de Publicité, 16, Rue Marcq, Brussels.
INTERAVIA BRAZIL:	R. F. Besnard, 91 av. Almirante Barroso, S. 417-419, Rio de Janeiro. 131, rua Marconi 5° And., Sao Paulo.
INTERAVIA CANADA:	Wm. Dawson Subscription Service Ltd., 60 Front Street West, Toronto, Ontario.
INTERAVIA DENMARK:	Dansk Centralagentur, Stormgade 20, Copenhagen.
INTERAVIA FINLAND:	Akateeminen Kirjakauppa, Keskuskatu 2, Helsinki - Rautatiekirjakauppa Oy, Köydenpunojank 2, Helsinki.
INTERAVIA FRANCE:	144, Champs-Elysées, Paris VIIIe.
INTERAVIA GERMANY:	Ausland-Zeitungshandel W. E. Saarbach, Gereonstrasse 25-29, Cologne 1. Postal Cheque Account Cologne 25823.
INTERAVIA GREAT BRITAIN:	Interavia (United Kingdom) Ltd., 2-5, Old Bond Street, London, W.1.
INTERAVIA HOLLAND:	Rotterdamsche Couranten-Import en Kioskenonderneming v/h van Ditmar, Postbus 262, Rotterdam.
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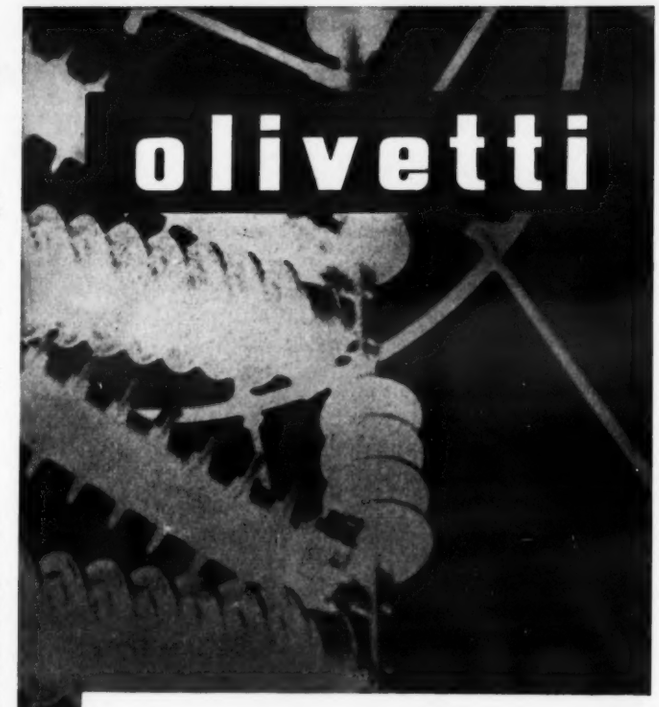
INTERAVIA URUGUAY:	R. F. Besnard, Edificio Artigas, Rincôn 487, Montevideo.
INTERAVIA U.S.A.:	385 Fifth Avenue, Room 1408, New York 16, N. Y. Subscriptions also from the International News Co., 131 Varick Street, New York, N. Y.

Copyright 1952 by Interavia S. A., Geneva, Switzerland

Printed in Switzerland

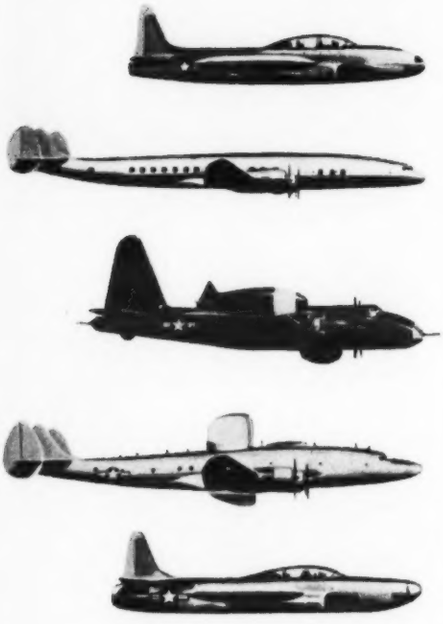
Imprimeries Populaires, Geneva — Héliographia S. A., Lausanne
Imprimerie de "La Tribune de Genève", Geneva



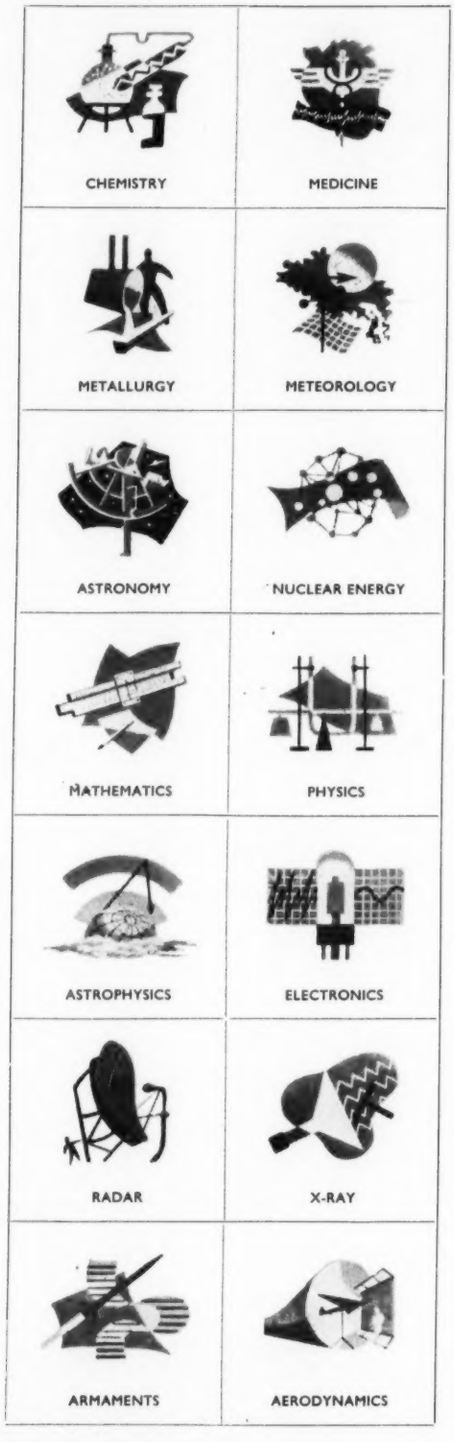
Lexikon Elettrica

Greater output with less fatigue

Leadership demands constant achievement



T-33 JET TRAINER
SUPER CONSTELLATION
P2V NEPTUNE
MILITARY CONSTELLATION
F-94 STARFIRE



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AIRCRAFT DESIGNING and construction are *precise* sciences. That's why Lockheed Engineering has more departments than a big university.

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Look to Lockheed for Leadership

Lockheed

Announces New "Super Constellation" Orders from 6 Airlines

The Constellation production line is now at its highest peak in history, following receipt of new orders for Super Constellations from six world airlines recently announced by Robert E. Gross, president of Lockheed Aircraft Corporation. So far a total of 85 Super Constellations have been ordered, bringing orders for all Constellation models to 392, not including military production.

Super Constellations will be the first commercial airplanes to use compound engines, and with this added power they will be the fastest air transports ever built in the United States.

The six airlines placing new orders for Super Constellations are Iberia of Spain, AVIANCA of Colombia, Air India, Braathens South American and Far East Airtransport, and includes re-orders from KLM Royal Dutch Air Lines and QANTAS Empire Airways of Australia.

Twelve leading world airlines have now bought Super Constellations, and 20 have ordered either Constellations, Super Constellations or both. Also a substantial quantity is on order for the U.S. Air Force and U.S. Navy.

Key to the worldwide acceptance of this most advanced American transport is its extreme built-in versatility. Carefully designed to meet changing airline traffic conditions, the seating arrangement can be quickly and easily changed between flights from luxury accommodations for 47 to as many as 94 passengers. And the Super Constellation is probably the first airplane ever predesigned with sufficient structural strength to allow for a large increase in takeoff weight (from present 130,000 lbs. to as much as 150,000 lbs.) without further modification. It is designed to utilise either Allison or Pratt & Whitney turbo-prop power plants, which will increase top speed from 379 to 449 miles per hour. The first two with turbo-prop power, on order for the U.S. Navy, will fly next year.

Super Constellations with turbo-prop engines may well become for many years the economical "work-horse" of the commercial airlines, carrying volume passenger traffic most economically at high speeds, or as much as 19 tons of freight over long distances.

Production of the Constellation has continued uninterrupted for seven years, culminating in the Super Constellation. And today Lockheed is not only at the peak of production on this ever more popular transport but continues to maintain leadership in jet aircraft production.

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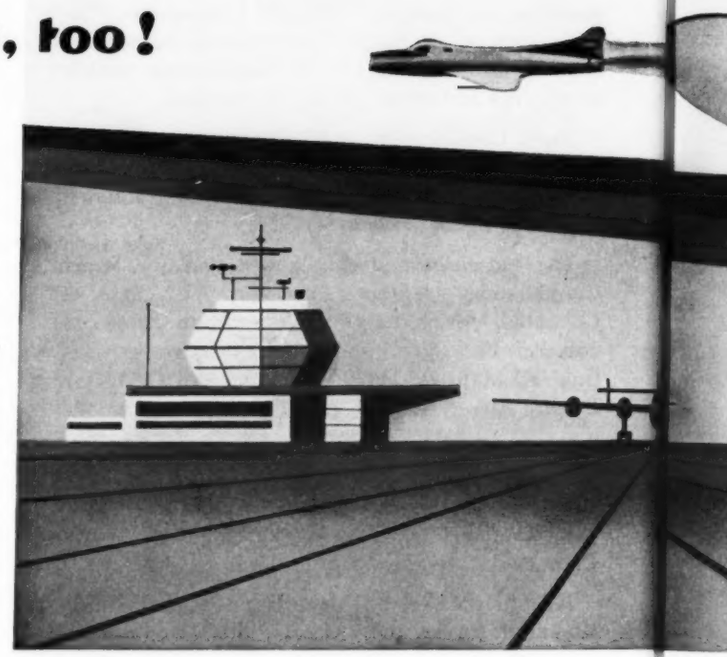

If you are in the aviation industry, *in any capacity whatever*, Bendix is an important factor in your life and your livelihood.

Look at the record. More planes fly more miles with Bendix radio equipment than any other make. Bendix ignition systems are virtually standard for the industry. Bendix has successfully solved fuel metering problems for every type of plane. Bendix is a foremost force in the development of equipment for automatic flight and all-weather landing.

And these are only the highlights of Bendix activities in aviation. Actually, no other single organization builds so many products essential to the safety and efficiency of modern planes. No other concentrates such a wide range of skills and talents on this industry's problems. As a result, none has a finer record of achievement in this ultra-progressive field.

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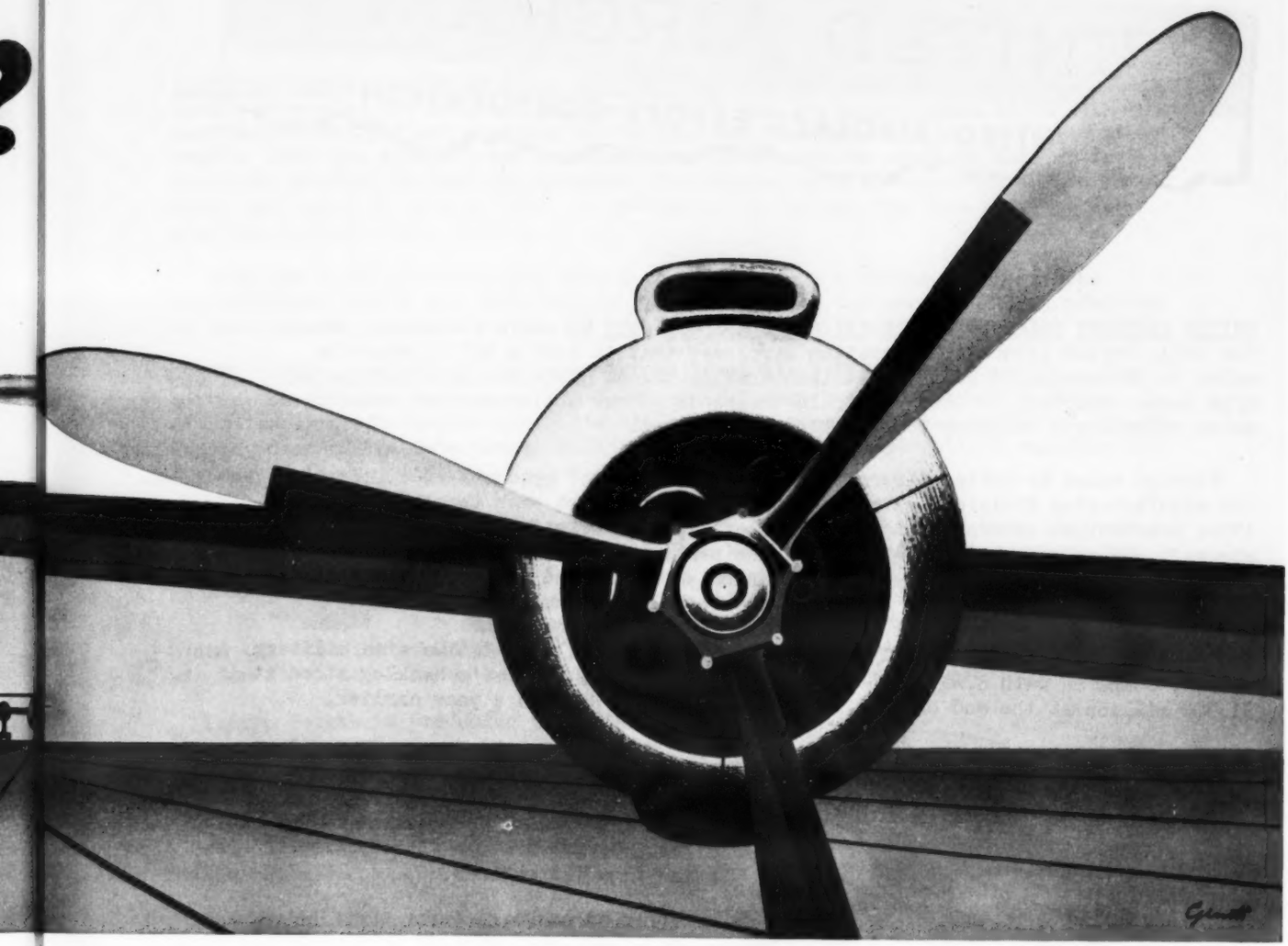

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UNITED AIRGRAM

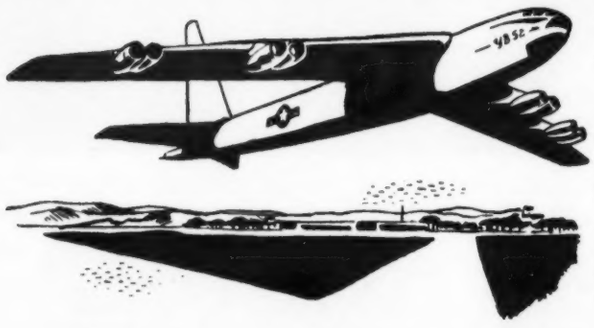
UNITED AIRCRAFT EXPORT CORPORATION

UNITED AIRCRAFT SALES UP 55% IN '51, BUT NET ROSE ONLY 8% -- In its annual report for 1951, United Aircraft Corporation disclosed that it took a 55% increase in sales to produce an 8% gain in net income after taxes. This was a reflection of high costs necessary to tool up, train thousands of new employees, and other costs which accompany a build-up to high production level.

Foreign sales by United Aircraft Export Corporation of products of all four of its manufacturing divisions were considerably greater last year than they were in 1950. Substantial orders on hand at December 31, 1951 were for engines, propellers, aircraft and spare parts. Substantial spare parts orders reflect the extensive forward provisioning that foreign airlines which use United Aircraft's products must do because of lengthened schedules due to military demands.

Of United Aircraft's total 1951 sales of over $417 million, 84% were in military orders, compared with 87% of 1950 sales of $269,255,000. United's backlog stood at $1,300 million at the end of 1951, compared with $715 million a year earlier.

PRATT & WHITNEY POWERED JET BOMBERS MAKE INITIAL TEST FLIGHTS -- Two new U.S. Air Force jet bombers made successful first flights in April. They were the Boeing Aircraft YB-52, and the Consolidated Vultee YB-60. Both are powered by eight powerful Pratt & Whitney J-57 axial flow jet engines.



The B-52 made its initial flight on April 15 from the airport adjoining the Boeing Aircraft plant in Seattle. The flight lasted for two hours and fifty-one minutes, and was concluded at Larson Field, near Moses Lake, Washington, an Air Force testing center.

The second of the Air Force's eight-jet intercontinental bombers, the swept-wing Consolidated Vultee YB-60, made its first flight at Carswell AFB, Fort Worth, Texas, on April 18. It remained aloft for one hour and six minutes.

According to an account in the New York Herald Tribune "...both the YB-52 and the YB-60 were built to the same basic requirements laid down for the B-36 -- the ability to carry a 10,000-pound bomb 10,000 miles without refueling. They are equipped with Pratt & Whitney J-57 Turbo-Wasp jet power plants developing about 10,000 pounds of thrust each, or the equivalent of 10,000 horse-power at jet plane operating speeds and altitudes..." Unfortunately, the performance figures on these airplanes and on the J-57 engine are classified and cannot be published.

HAMILTON STANDARD SUPPLIES VITAL EQUIPMENT FOR NEW JET BOMBERS -- America's newest intercontinental jet bombers, the Boeing YB-52 and the Consolidated YB-60 each use equipment developed and produced by the Hamilton Standard Division of United Aircraft. Both new aircraft are equipped with turbine engine starters and jet fuel controls supplied by Hamilton Standard. The starter is a comparatively new product, first announced in October 1951. It substantially reduces the time required for starting turbine power plants.

Hamilton's jet fuel control, also a new product, is a device which governs turbine-wheel speeds and restricts by direct "sensing" the amount of fuel admitted to the combustion chambers when the engine's operating temperatures rise.

CHANCE VOUGHT AIRCRAFT HAS DESIGNED AND BUILT TOP NAVY PLANES FOR 35 YEARS --June 1 marked the 35th anniversary of the founding of Chance Vought Aircraft Division of United Aircraft Corporation. Its steady growth since 1917 has reflected the advanced ideas of the late Chance Milton Vought, brilliant aeronautical engineer and founder of the company.

The record of Chance Vought "firsts" is both long and impressive. The U.S. Navy's first aircraft carrier, the U.S.S. Langley, was equipped exclusively with Vought VE-9s. The Vought UO-1 was the first to prove the practicability of catapulting planes from battleships and cruisers; a Vought plane was the first folding-wing monoplane; and the F4U Corsair, before World War II was the first 400-mile-an-hour fighter in the country.

Today, Vought is producing two outstanding planes for the U.S. Navy. One is the AU-1, especially designed for close air support. Although extensively modified, it basically follows the original F4U Corsair design laid down in 1939 -- a dramatic instance of Vought's far-sighted designing.

The other is the sleek-looking Cutlass, a tailless, swept-wing fighter, powered by twin-jet engines and afterburners. It was designed to out-fly and out-fight any other carrier-based aircraft in the world.

Still another version of the Corsair in production in 1952 is the F4U-7. It is being made for the French Government under the Mutual Defense Assistance Program. Similar to the World War II F4U-4, the F4U-7 carries heavier armor and armament.

SIKORSKY S-55 IS CERTIFIED FOR COMMERCIAL USE -- The first transport-type helicopter in the world to be approved for commercial operation, and to receive a certificate of airworthiness for export, is Sikorsky Aircraft's big S-55. It was granted these certifications by the Civil Aeronautics Administration last March.

The S-55 is the basic design from which Sikorsky H-19 and HRS military versions were built. Both of these models have seen outstanding service in combat since their introduction there in the Spring of 1951. In fact the performance of these models has been so impressive that similar versions have been ordered by all branches of the U. S. military services.

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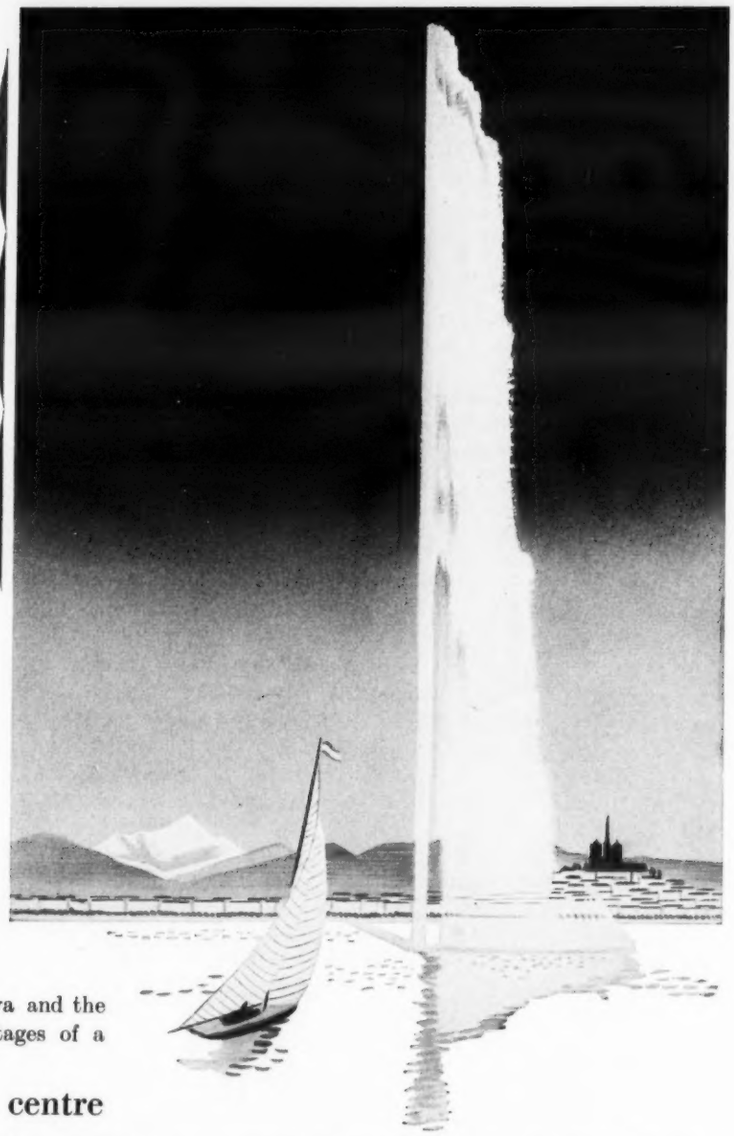

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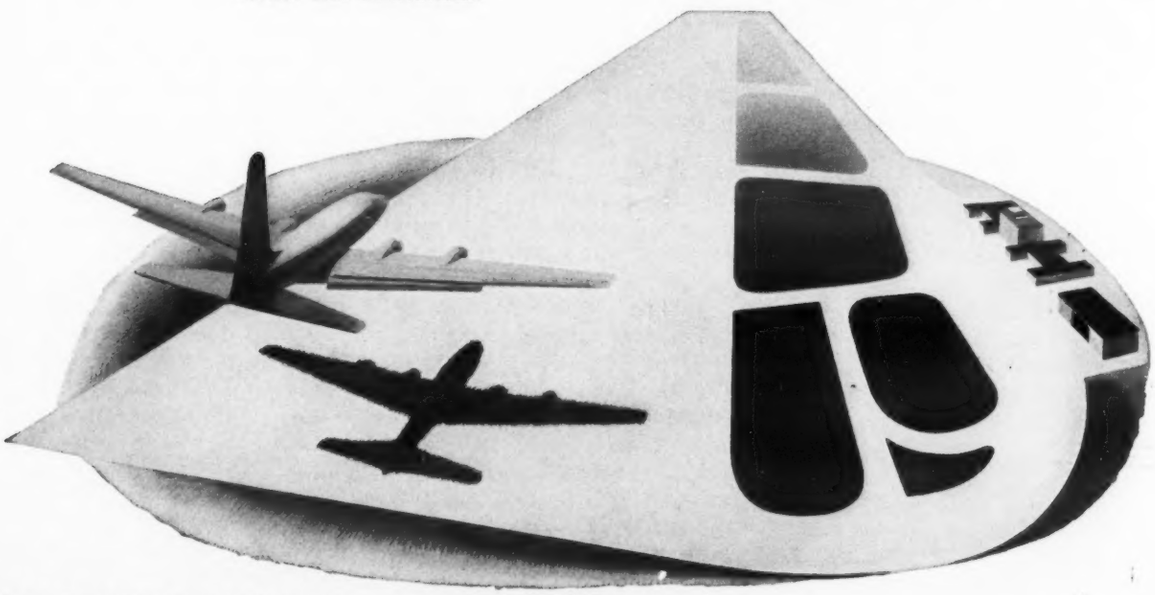
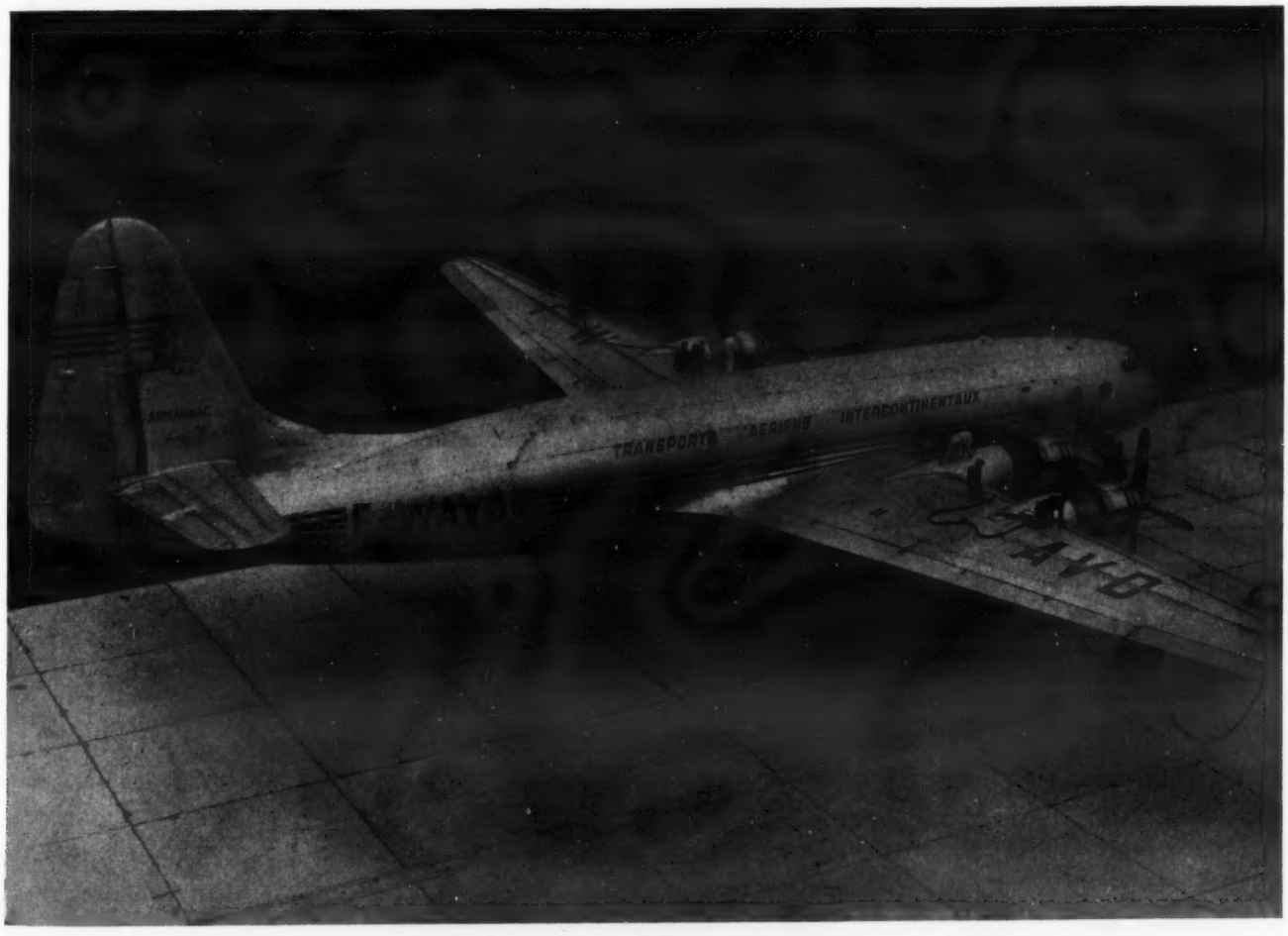


INTERCONTINENTAL AIRPORT

L'Armagnac

at Toulouse-Blagnac on the eve of its endurance tests



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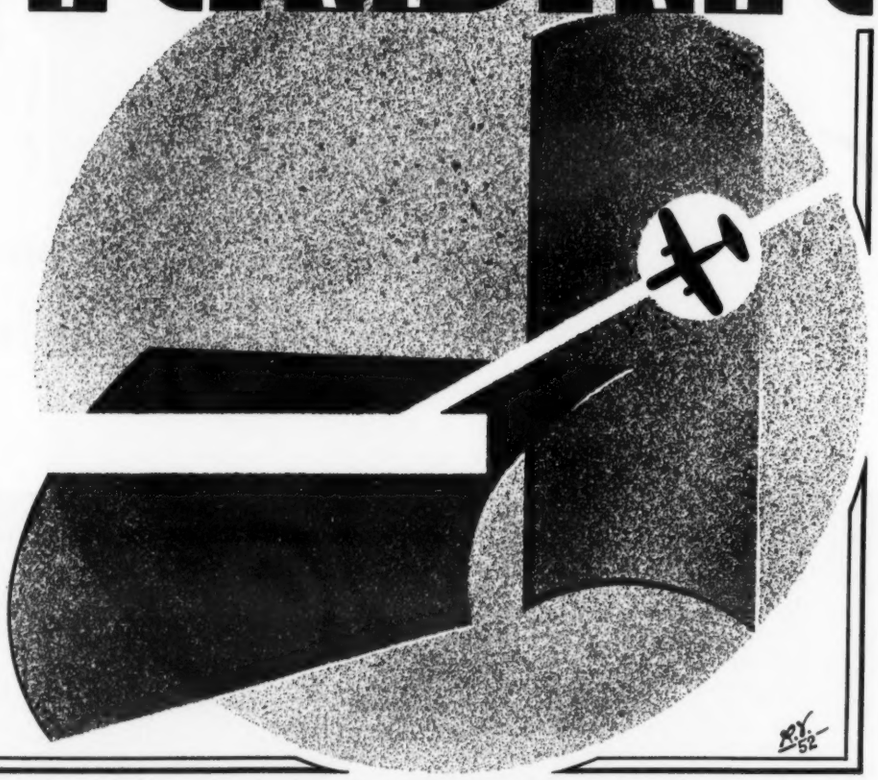

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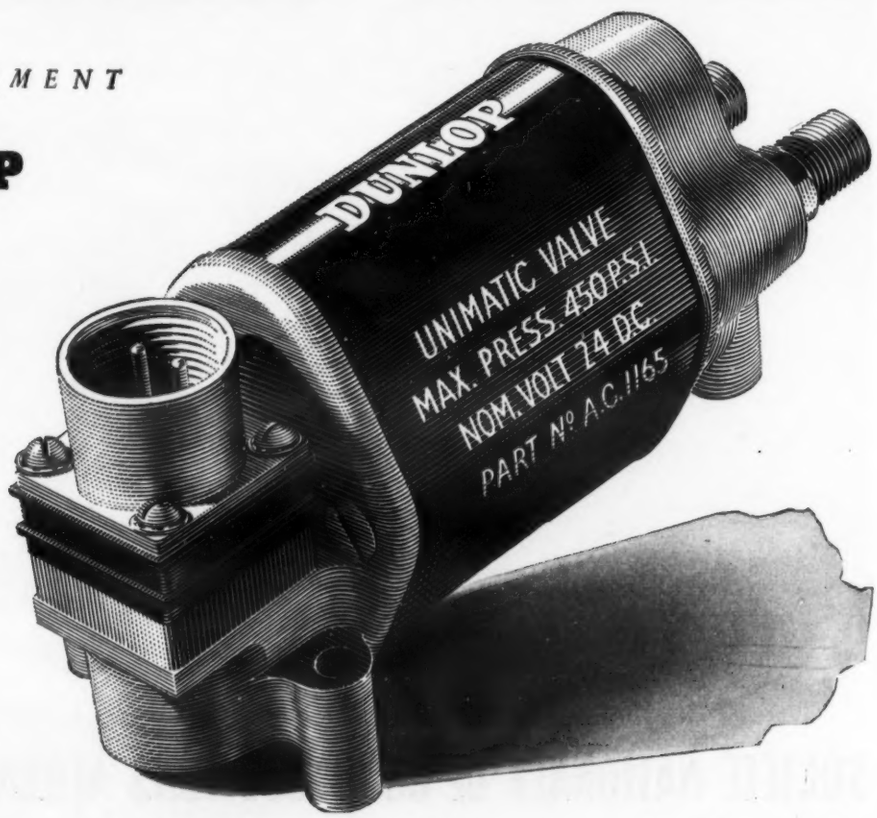
BY **DUNLOP**



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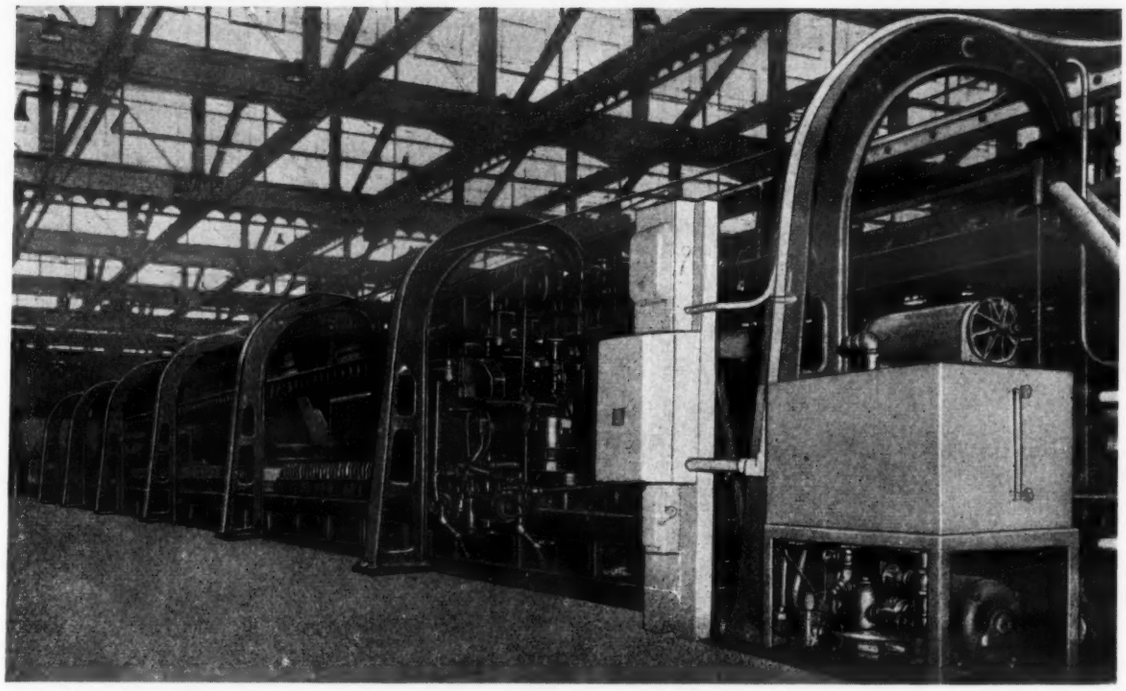


Typical of Canadair's fine equipment :
a huge spar cap milling machine.

WHAT IS CANADAIR'S *Production Capacity?*

Canadair's production capacity is something that never fails to amaze the many executives of the industry and military officers visiting the plant.

It is a capacity great enough to handle the simultaneous production of 3 types of military aircraft . . . for the Royal Air Force, the Royal Canadian Air Force and the United States Air Force.

It is a capacity great enough to have built fleets of luxury airliners for Trans-Canada Air Lines . . . British Overseas Airways Corporation . . . Canadian Pacific Airlines . . . and military transports for the Royal Canadian Air Force.

It is a capacity that has the key production essentials . . . facilities, men, designers, engineers and experience . . . a potential of definite interest to those with future plans to buy aircraft.

For further information: European Representative, J. H. Davis, Princes House, 190 Piccadilly, London, W1, England.

Vignettes of
CANADA—AIR LAND

A few weeks ago a large Canadian Corporation took delivery of a greatly modified C-47 — remodelled into an efficiently equipped office.

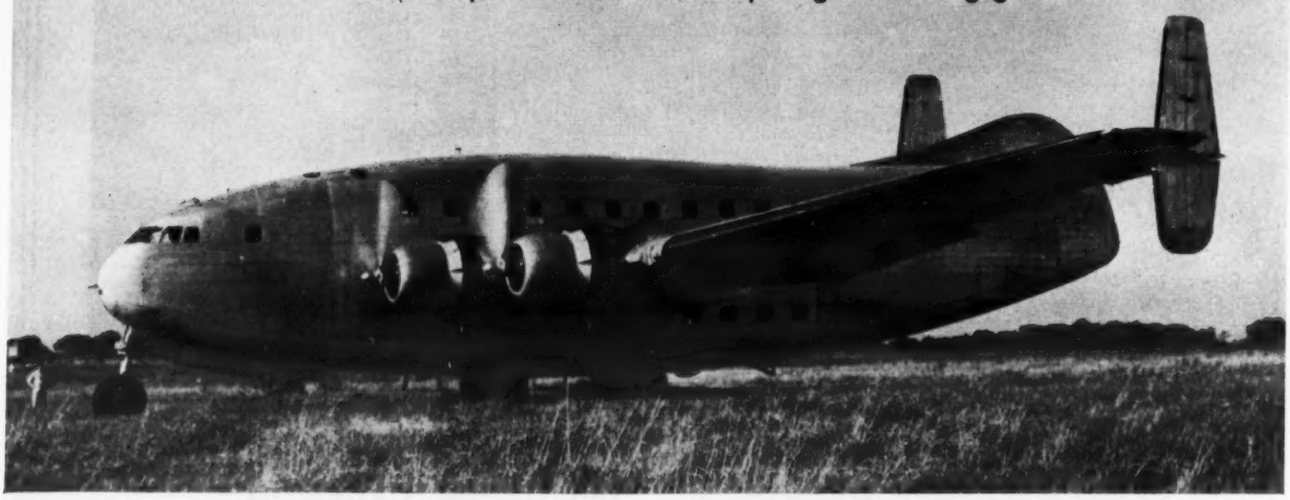
In a country of vast distances like Canada, business executives constantly face problems of time lost in travel. The 'flying office' is a typical Canadian answer.

In dozens of ways, from executive work to prospecting for oil, Canadians continue to make the airways an essential part of daily business.

Canadair
LIMITED, MONTREAL, CANADA

L'aménagement en version « Coach »
du **BREGUET 763 « Provence »**
sur les lignes de la Cie AIR FRANCE

comporte { au pont supérieur : de 59 à 69 passagers
au pont inférieur : 48 passagers et bagages



PROGRESS IN INSTRUMENT LANDING

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ONE AIRCRAFT RECEIVER
ONE CARRIER WAVE

THREE READINGS
★ Localizer
★ Glide path
★ Distance aircraft-runway

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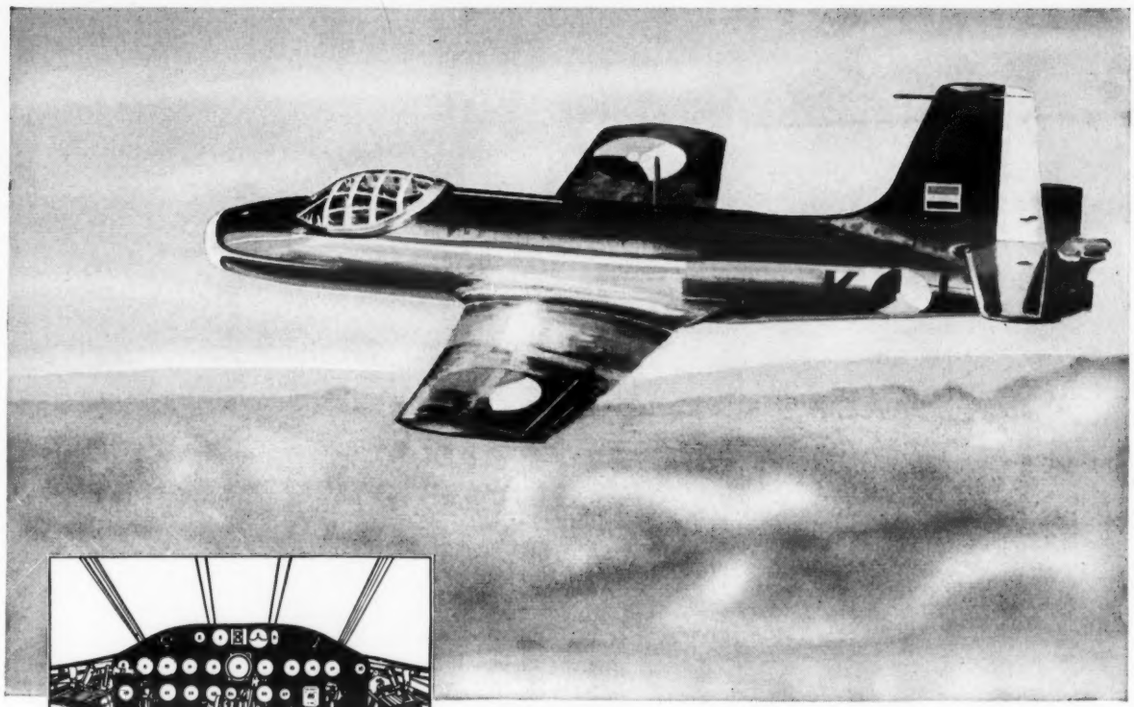

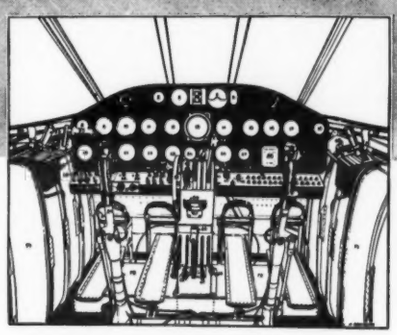

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HERE, AT LAST, IS AN AIRCRAFT THAT IS *designed* AS A JET-TRAINER!

In Fokker's S. 14, with Rolls Royce Derwent jet - engine, instructor and pupil are sitting side by side. It provides, as these figures show, for the pupil, a well calculated step between his advanced-trainer and the operational trainer and fighter he is to fly tomorrow.

SPEED AND WING LOADING OF AEROPLANES FOR ADVANCED TRAINING

	Average for piston engined trainers	Fokker S. 14	Average for converted jet fighters
Max. speed mph	260	435	560
Wing loading lb/sq.ft.	26	32,2	45

Royal Dutch Aircraft Factories Fokker

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Consumption 20 litres per 100 km

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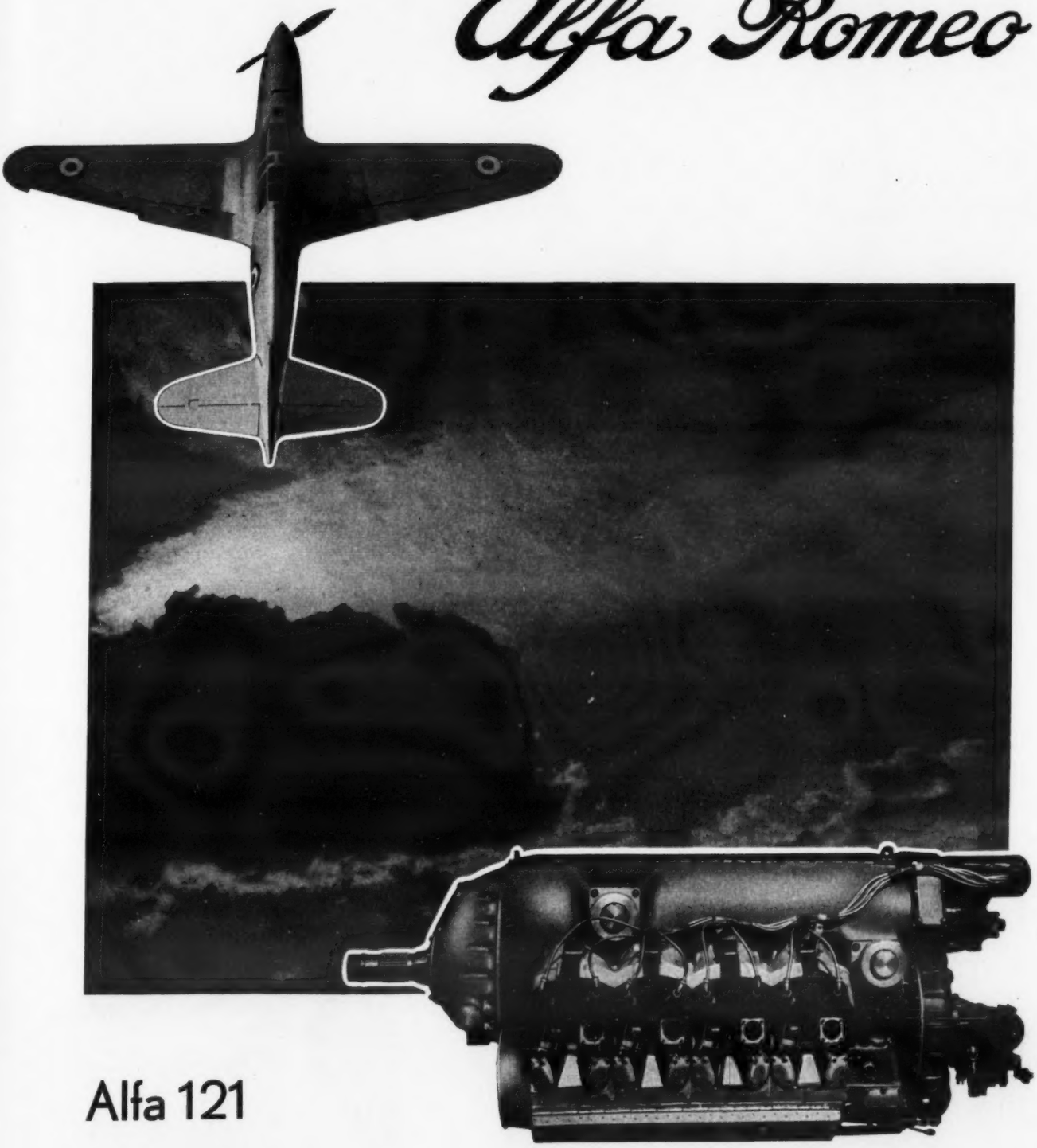

Alfa 121
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To all seasoned air travellers the name "Constellation" has come to symbolize reliability, speed and comfort.

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ALL TRAVEL AGENCIES AND 119 CHAMPS-ÉLYSÉES - BALZAC 70-50 - 2 RUE SCRIBE - OPÉRA 41-00

These figures speak for themselves:
In 1947 : 423,115 passengers
In 1950 : 774,906 passengers
In 1951 : 1,000,000 passengers

Mid-Year Review

Early June... The present issue will be in the hands of the reader by July 1st, 1952. This is therefore a good moment to present a brief interim balance of the first six months of the current year.

Air Forces

At the beginning of issue No. 1 this year an attempt was made to describe the "Outlook for 1952." Certain tendencies noted then have been confirmed. For the world's air policies on the whole it is of very little importance whether the American Air Force appropriations—over which President Truman and his Defense Secretary Lovett are still battling with Congress—are reduced by three or by five thousand million dollars. The fact that they have been cut down at all is illuminating. Under present-day peacetime conditions, in spite of the cold war, there is still a long way to go before the 143-wing programme is completed. And there can be no question yet of an annual production capacity of 50,000 front-line aircraft, such as the President asked for early in 1951, following in the footsteps of his predecessor. *If, however, the American armament machine, the mightiest in the world, cannot reach the desired pitch, there must be serious reasons for this. To throw some light on these reasons is the main object of this issue.*

To imagine that such huge quantities of "luxury aircraft with ashtrays and air-conditioning"... with sonic speeds, long range, high ceiling, electronic equipment, heavy armament... and an instrument panel like that on the bridge of a battle cruiser... can be built and paid for in peacetime is wishful thinking.

The following pages contain contributions on this subject from a well-known French officer and a German who may perhaps be equally well-known tomorrow, a British and a German engineer, and an American scientist of world renown.

With merciless logic the Frenchman argues that the only way out of the impasse at which aircraft industry and air forces in all countries appear to be arriving is the "expendable aircraft." From here the way must lead sooner or later to the guided missile. The German officer is not so sure. He feels that the "expendable aircraft" comes too close to the idea of the "Kamikaze suicide weapon," a principle that would never be acceptable to Western philosophy. The German engineer would like to see the last developments of World War II followed up and thinks that the "People's Fighter" which he brought out in the final phase before the German collapse, may yet provide a solution, if present-day technical knowledge is utilized. The British engineer ? He cannot yet entirely free himself of the British tradition of quality and sees, somewhat conservatively, the success of all air forces in first-class products, even if they are costly and difficult to produce. And the American scientist and aerodynamicist of world reputation seeks a practical solution through the use of auxiliary equipment such as take-off rockets, since he can visualise no other way out for today's over-refined flying equipment.

Once again the experts are divided in their opinions. Perhaps the spirited Frenchman with his ruthless logic is right after all ! At any rate he has an ally across the Atlantic, in one of the cleverest, most successful aircraft manufacturers of the New World : J. H. Kindelberger, President of North American Aviation, has scarcely ever made a mistake —except for a brief and unsuccessful venture in sports aircraft production on the side—and has never lost a cent. Speaking to businessmen in Detroit early in May, he said : "... the machine is getting far ahead of man. It is forcing us closer and closer to the concept of leaving the pilot out. Our flying machines are rapidly approaching capabilities that are penalized rather than aided by the presence of a human pilot." Guided missiles are the weapons of the future, "and our nation must arrive at that crossroad first if we and our way of life are to survive..." Yet this same Kindelberger is now building large quantities of the F-86 Sabre "luxury" fighter, which has proved its worth against the MiG-15 over the battlefields of Korea. One would expect him therefore to be the last to advise against high-performance aircraft, with the consequent risk of reducing Sabre production.

The first six months of 1952 have shown that the burden of rearmament, both financial and industrial, is forcing military aircraft engineering towards a parting of the ways. Conventional military aircraft production leads inevitably into an impasse. Too little attention has been given to the human factor, and now the robot is on the horizon.

Air Transportation

At last there were carefree faces among the managements of the world's airlines at the beginning of 1952. The results for 1951 were now more than a vague hope. Last year over forty million passengers were carried on scheduled air services and roughly one thousand million dollars—in the United States alone—taken by this youngest transportation branch. Here, too, the New World was in the lead ! [1]

Suddenly, however, C. R. Smith, President of American Airlines—also one of the cleverest and most successful men in his field—discovered that something was not quite right in the general scheme of development. Net profit for the first quarter of 1952 was, for no visible reason, 70% below that for the corresponding period last year. Yet business was wonderful ! Here too "luxury aircraft with ashtrays and air conditioning," which constantly need replacing, are a heavy burden. Personnel has got short and expensive, thanks to rearmament, which also swallows up more and more taxation... and receipts, high as they are, can no longer keep pace with ever-increasing costs. Sir Miles Thomas, first gentleman of British air transport, had gradually been losing his engaging smile and was now looking more worried. Such was the picture up to April this year.

What happened in May 1952 ? A relatively small group of 90,000 workers in the American oil industry went on strike for two weeks. In so doing these 90,000 throttled the whole of international air transport overnight, since all airlines were ordered by their Governments to cut down their schedules for four weeks, so as to save 35% fuel. What this shortage of petrol has cost the airlines will not be known until early in 1953. The effect on the airlines' booking offices is known already to all those travellers whose business arrangements have been painfully upset by it. The American unions had also chosen the most awkward moment for their action, since this seriously threatened the delicate seedling of Atlantic tourist-class services planned for May 1st.

*

All these are merely items in an interim balance. By the end of the year we shall be able to see more clearly and, it is to be hoped, to draw up a favourable final balance. *EEH.*

[1] Cf. *U. S. Airlines in 1951.*

Short-Life Aircraft

The West Turns out its Pockets

Can air defence be bought more cheaply?

BY LIEUTENANT-COLONEL
PIERRE M. GALLOIS, PARIS

To increase the nation's standard of living and simultaneously assure its safety through power; to win the economic battle and the arms race at the same time; to have a well-lined pocket-book and powerful fists . . . these are the guiding lines governing the policies of the West. Its gigantic armament machine is set to pour out huge quantities of powerful weapons—as soon as its gears are greased with gold.

There is nothing more simple than to establish a defence plan, to assess the size of the armed forces that are required, to determine the individual phases of growth and to estimate the costs. In the calm atmosphere of the project offices and in the limelight of public opinion strategists and arms specialists have worked on such plans for many years. Difficulties begin to crop up the moment military demands and economic potentialities must be adapted to each other, in other words, when the financial wizards are called in to study the strategic plans of the general staff. The Joint Chiefs of Staff of the USA were subjected to this painful procedure only a few weeks ago, when the U.S. Congress began to scrutinize the plans to expand the U.S. Air Force to 143 wings by 1954. On the international plane, the projects elaborated by the military were recently torn apart by the economists at the Lisbon conference. In view of the acknowledged fact that increasingly rigid specialization is required in most fields of human activity, it might seem strange that civilian outsiders have the final say on military matters. However, in the final analysis this procedure is neither paradoxical nor unfair, since it accurately reflects the spirit of the defensive organization which the West is striving to build up.

Speaking in London on the occasion of his farewell visit, General Eisenhower listed the three decisive factors needed to maintain the peace: moral force, economic strength and, lastly, military power. In consequence, the defence plans of all Atlantic nations are now

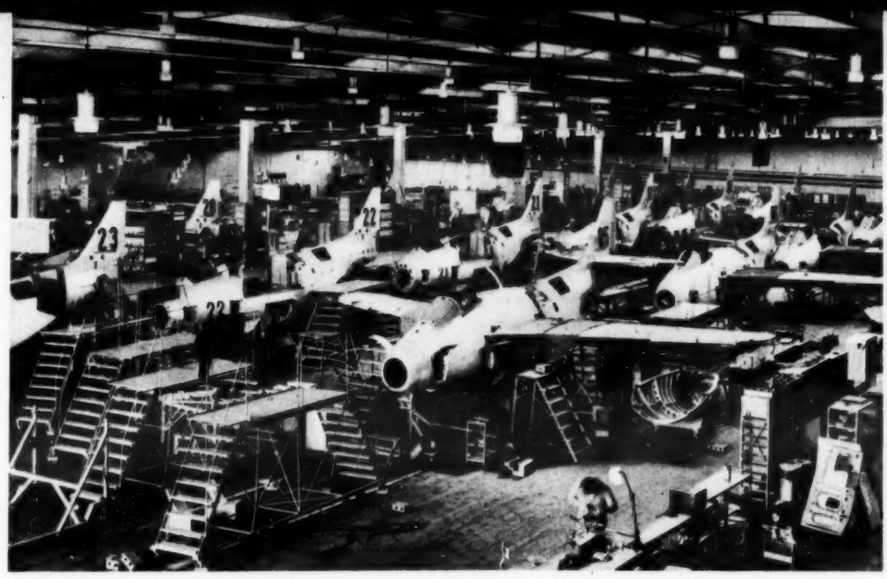
F-86E "Sabre" production line at the Los Angeles plant of North American Aviation, Inc.

being closely studied to determine whether they offer optimum efficacity at lowest cost. The general staffs are more or less familiar with the financial resources available for their countries' defence effort. It is their duty to squeeze the maximum defence readiness out of each appropriated dollar, pound or franc.

In the course of the defence debate in the House of Commons, Britain's new Parliamentary Under-Secretary for Air, G. R. Ward, made no bones about the difficulties which the expansion of the Royal Air Force is encountering. In Britain, too, it has been found necessary to concentrate on the most urgent tasks. For example, it was decided not to enlarge RAF Transport Command, because the other branches of the Service will exhaust the available credits. Chief of all, the Under-Secretary emphasized the importance of reducing the complexity and maintenance of modern flying equipment. He stated that the Air Ministry were investigating means of *radically simplifying certain specialized types of fighter aircraft.*

"It can be done"—and its hazards

It is obvious that Europe has the same worries as Britain, and the only surprise lies in the fact that the men in responsible positions did not attack these problems long ago. The initiated are not astonished at the present cost of producing aircraft. The study conducted in 1947 by the U. S. Air Policy Commission, the testimony furnished by a vast number of witnesses questioned at the time by Thomas Finletter and his aides, the wide circulation given to the Commission's final report, "*Survival in the Air Age,*" should have opened many eyes and set off extensive research programmes based on the new technical and economic realities, which differ profoundly from those valid at the end of the late war. Since the national income per inhabitant this side of the Atlantic amounts to a fourth or a fifth of that of every American or Canadian, the first move towards reducing manufacturing costs should logically have been made in the Old World. The United States not only possesses unequalled resources, but its national talent of performing almost incredible engineering and production miracles has also conditioned the public mind into acceptance of virtually any financial hat-trick. The phrase "it can be done," with which the American engineer greets the boldest production plans, is being applied also to the biggest problem confronting the West, and particularly America, today. To rearm and at the same time to improve one's living standard ? *It can be done* . . . To pursue this policy not only in the United States but also to help other nations to practise it ? *It can be done* . . . To mass-produce combat aircraft of peak performance, fitted with every conceivable kind of equipment, from ashtrays to air-conditioning ? *It can be done* . . .



SAAB J 29 final assembly at the company's Linköping factory.

Today the question of whether everything really "can be done" is of critical importance everywhere, including the United States, and sometimes it seems that the money-barrier is more difficult to overcome than the sonic barrier.

Since 1946 the Congress has voted about $42,000,000,000 for the U. S. Air Force. Considering the enormity of this amount, it is understandable that American Congressmen were somewhat flabbergasted when the Chief of Staff of the USAF recently referred to the Service being "run on a shoestring." It is probable that this qualification was not employed objectively, but was used politically to impress on Senators and Representatives the urgency of the Air Force's expansion programme. However, the fact remains that the President of the USA slashed about $4,500,000,000 from the Air Force Appropriations Bill for 1952, and the Congress ordered further cuts, leaving a total Air Force budget of only $20,000,000,000. For the 143-wing expansion programme this means a delay of about three years and a production cut of about 4,000 aircraft per year.

In other words, economic and financial factors play an equally important rôle on either side of the Atlantic.

Must a combat aircraft cost $2,500,000 a year ?

It is difficult, if not impossible, to make direct comparisons between the air forces of the various nations. Each country uses a different yardstick when measuring its budget, personnel establishment, first-line strength, etc., so that speculation about the "economic efficiency" of an air force is hazardous. Nevertheless, a cautious interpretation of available figures and the allowance of wide margins for possible errors permit an approximate estimate of annual cost in the USSR, the USA, Britain and France.

	USSR	USA	Great Britain	France
Annual cost ('000 $)	9,000,000 ?	20,000,000	1,500,000	1,000,000
Personnel strength	750,000	900,000	280,000	180,000
First-line aircraft	18,000*	8,000	1,800	800 *

* Estimated

Although this table is of limited value because no accurate details are available, it nevertheless shows that one first-line aircraft takes a slice of about $500,000 out of the Soviets' annual budget, whereas the Americans are willing to spend $2,500,000 on it. The number of air force personnel needed for each first-line aircraft varies from 40 to 200 men (USSR and France). It is evident that the smallest air force is the most exacting in this respect, because the heavy "general overhead" is spread over only a small number of first-line units.

North American F-86D all-weather single-seater fighters receive their complicated electronic equipment.

A single F-86 "Sabre" costs nearly as much as . . . two flights of F-51 "Mustang" single-seater World War II fighters, a type widely used for escort duties protecting U.S. heavy bombers on their missions over Germany and Japan.

The lion's share of air force appropriations is absorbed by personnel and materiel. On the whole, personnel costs are assumed to use up about 25 to 40 percent and materiel 30 to 45 percent of available credits, depending upon the state of development and the expansion plans of an air force. The balance is spent on ground organization, miscellaneous equipment and administration.

It is clear that measures of economy will yield the greatest results if applied to personnel and materiel. Of the latest USAF appropriations of about $17,000,000,000, approximately $7,000,000,000 was spent on aircraft, parts and equipment procurement and $3,500,000,000 on personnel. The British estimates for 1952 (£467,000,000) provided $190,000,000 for equipment and £90,000,000 for personnel. France, in 1951, spent 47 percent of its entire Air Force credits on production and development, and 32 percent on personnel.

Personnel is therefore quite expensive to maintain. It may be assumed that a relatively powerful air force of 2000 aircraft of all types requires about 160,000 men. Less than ten percent of these are aircrew, and more than 60 percent are specialists and technicians trained at considerable expenditure of time and money. In addition, an air force of 2000 aircraft will need roughly 20,000 motorized vehicles and an impressive maintenance, overhaul and supply organization.

This is a heavy burden, especially for the Western countries, who cannot afford to introduce extended periods of military service for special branches of the armed forces and who, in times of peace, cannot keep under arms a personnel strength of sufficient size to ensure the full success of the specialist training programmes.

A heavy shaft for a small spearhead

Considerable reserves of men, machines and money are needed to keep conventional aircraft operational. Depending upon their degree of wear or damage through accidents or enemy action, aircraft pass through a greater or smaller number of stages of the maintenance organization, ranging from field maintenance units to the manufacturing plants. An immense shuttle movement occurs between the service aerodrome and the rear, and at each stage of this flow a vast number of hands and parts must be kept in readiness.

The "striking point" of an air force is thus supported on a very broad basis, which technically is of decisive importance but militarily remains inactive. The trouble is that without it air power is not possible. It happens sometimes that in sparsely populated or economically less powerful countries, the available money is entirely used up for building up the technical basis of the air force, so that nothing is left over for the actual striking weapon. This danger increases with the growing complexity of modern aircraft, with the result that below a certain minimum number of operational combat aircraft there exists a grotesquely disproportionate administrative and maintenance colossus, the cost of which cannot justify the attainable results. The air arm is thus stifled by its own supporting services.

Fighters and medium bombers of World War II required a minimum of 20 to 25 hours of maintenance and repair work for each hour of operational flight. For more extensive work at the repair and overhaul centres in the rear up to 200 man-hours may be necessary per hour of flight in times of peace and much more in times of war owing to accelerated attrition of equipment. In the present state of engineering a fighter aircraft with an operational life of 100 flying hours probably requires no less than 100,000 man-hours. In other words, each hour of life necessitates 1000 man-hours of labour, or to express it even more graphically : *1000 man-hours of labour are needed to obtain a firing time of 30 seconds.*

These man-hours are no longer performed by unskilled labour. Six years ago the American aircraft industry counted one qualified engineer for every 22 skilled workmen. Today there is one engineer for eight skilled workers. While one electronics engineer used to be sufficient for 1,000 workers, there is one electronics specialist for every 24 workers today. It is not surprising that the U.S. aircraft industry is frantically calling for trained engineers and, in view of the present shortage, is happy to hire young people of a good general educational level and to train them at its own expense.

Complicated equipment largely accounts for the high cost of modern combat aircraft. Picture shows the instrument panel of a Lockheed fighter.

War or peace make practically no difference to the Air Force

The consequences of this evolution are very grave. While on the day of mobilization the army can multiply its effective strength almost instantly by three or four, the air force will need a considerable period of time for a similar expansion. In the air more than in any other domain those countries that plan for and can determine the date of the outbreak of war are greatly favoured. A similar advantage is held by countries protected by an ocean or an anti-

Germany's Bachem BP-20 "Natter" Expendable Fighter

Armament : 48 air-to-air rockets of 73-mm cal.

Filling in the rocket fuels ; at the stern the four booster rockets.

The pilot emplanes by means of a fire escape ladder and will "deplane" by parachute.

All five rocket engines have been fired. The "Natter" takes off vertically and is guided into an oblique trajectory only after reaching a height of about 1,000 metres.

tank moat, or by a range of mountains or other natural obstacles. This is the reason why, for nations not enjoying such protection, the idea of balanced air, naval and land forces is illusory. They must concentrate their entire energy on the air arm.

In practice this means that even in peacetime the air force should be maintained at full war strength. But in view of the high cost of raw materials, the economic, industrial and demographic factors, even major nations are incapable of keeping up such an air strength.

Very little that is new can be said about the cost and complexity of modern flying equipment. Theoretical studies have pointed to the decisive importance of this problem for many years. But it has taken the present rearmament of the West to unveil the full significance of the problem. Some people are beginning to be jittery, especially in the United States. Even the daily press offers the public the opportunity of comparing the prices of past and present aircraft types : whereas a North American F-51 "Mustang" fighter of 1944 could be bought for about $60,000, the simplest version of the North American F-86 "Sabre" jet fighter of today runs to more than $450,000. The Boeing B-29 "Superfortress" bomber cost $750,000, the Convair B-36 "Conqueror" ten-engined inter-continental bomber is priced at no less than $4,500,000. It has been said that a pound of modern aircraft costs as much as a pound of silver. But the price of the various weights making up an aeroplane is not at all uniform, and some components of the equipment are worth their weight in gold or platinum. In the old times eighty to ninety percent of the cost price of an aircraft was absorbed by airframe and engine. Today, radar equipment, automatic gun-sights and wireless instruments account for fifty or sixty percent of the much higher purchase price.

It sounds incredible that the STAE gun-sight of twenty years ago weighed only nine pounds and cost $150 ; the Norden bomb-sight of ten years later had already grown to a weight of 54 lbs. and a value of $6,000 ; whereas the K-2 electronic sighting equipment of the Convair B-36 and Boeing B-47 bombers tips the scales at more than a ton and represents an investment of about $300,000—which in World War II would have bought a whole B-17 "Flying Fortress" bomber !

Should the size of the defences be based on the life of the equipment ?

Faced by these difficulties, the great air powers decided radically to reduce the numerical strength of their air fleets. At the peak of its power in World War II the U.S. Air Force had 218 operational wings with about 40,000 first-line aircraft. In post-war years this fleet was first reduced to a so-called "safe minimum" of 126 wings with 7,500 aeroplanes. But even to maintain a strength of this size the entire annual budget of a country like France—with 42,000,000 inhabitants—would be needed twice over. So far as Britain is concerned, an annual production of 26,000 first-line aircraft, such as was attained in 1943, is simply out of the question today.

If the air fleets of the West are to be adapted to the higher costs and the demands of its economy, the West has no solution other than to divide the numerical size of its air arm by five . . . or even by ten.

Is there any way out of this labyrinth of prices, raw materials and manpower problems ? Ever since 1947 we have been endeavouring to give a few pointers in this direction. Quite different problems occupied the limelight at the time, however, and the requirements of adapting peacetime economy to defence demands was not of very topical urgency. Apart from that the public was still under the spell of the methods successfully employed in the last conflict and regarded any quest for new solutions as superfluous.

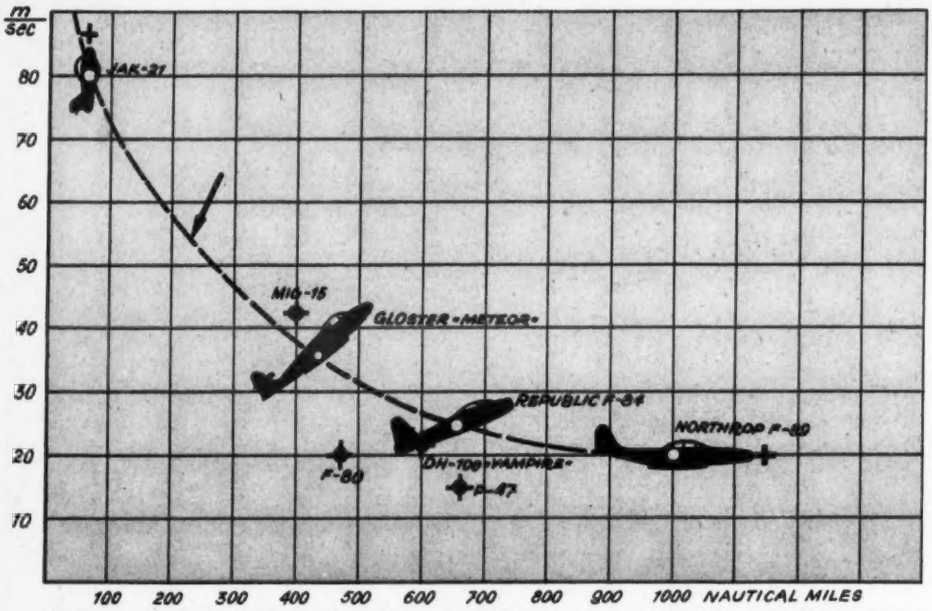
What are the factors which must be taken into consideration to discover the best approach to the new problems now facing the West ?

The first is clearly to define the military goals to be attained. The second is to study whether the advanced state of engineering, which has created such heavy demands and difficulties in the maintenance of adequate air power, does not itself provide means of simplifying manufacture and operation of modern aeroplanes.

Upon learning that the "average military life" of the modern first-line fighter is estimated at 80 hours in flight, of a fighter-bomber at 40 to 50 hours and of a medium bomber at 150 to 200 hours, the layman will quite rightly ask himself why the aircraft manufacturers are still designing aeroplanes for a life of tens of thousands of flying hours. It is a fact that there is very little difference between the conception of a fighter aircraft capable of surviving one or two months of intensive operation and that of a transport aircraft destined to operate on commercial air routes for ten years or more and a total of 20,000 or 30,000 hours of flight. Whether airframe, engine or equipment, the same care is taken in design and manufacture of both aircraft.

Engine specialists everywhere are working unceasingly to lengthen the endurance and the periods between overhaul of reciprocating and gas turbine engines, notwithstanding the fact that military aircraft stand a very good chance of being junked after less than eighty hours of operational flight. Milliards are spent every year simply to add a few dozen hours of life to the engines. At the same time, everybody agrees that the money thus invested would not pay dividends over any length of time.

The same applies to equipment. While its rôle is constantly increasing in importance and while its cost rises with the multiplicity of



Maximum performance at lower cost can be obtained through specialization. The diagram compares the rate of climb (metres per second) with the range (nautical miles) of a number of first-line jet fighters. Radical solutions are represented by the Yak 21 short-range rocket-propelled interceptor on the one hand, the Northrop F-89 "Scorpion" round-the-clock fighter on the other. Most other first-line fighters (e.g., F-80, F-84, "Meteor," "Vampire") are more or less successful compromises. They have neither sufficient range nor unusual rate of climb. Question : would an interceptor with a rate of climb of 50 to 60 metres per second and a range of 200 to 300 nautical miles be adequate ?

the functions it is expected to perform, the longevity demands of its military users have not diminished in any way.

Out of 100 million only 10 million pay off . . .

It can be assumed that an all-weather long-range fighter costing $1,200,000 (and requiring a stock of spares worth $600,000) should normally be capable of flying 2,000 hours, but that in wartime it would not last 200 hours. In other words, only 10 percent of the engineering and financial potential is utilizable for practical military purposes, and a sum of $100,000,000 must be ploughed into the business in order to obtain dividends on only 10 percent of that amount. Although these figures are tentative, they invite reflection and should encourage the search for a new formula.

The engineer's reply to observations of this sort will always be ready :

"My dear man, you want me to build aircraft capable of withstanding the heavy stress of aerial combat and equipped with a thousand instruments to offset the limitations of the human being that is flying it, and at the same time you want to save money, material and labour. If you think that you can build a rugged and efficient aircraft for a brief operational life ; if you are prepared to guarantee full reliability of functioning of every instrument, even over a short period, at lower cost, then you either don't know anything about our problem or you are the Wizard of Oz."

The reply seems pertinent. It is less pertinent if the problem is not considered as a whole but broken down into its components.

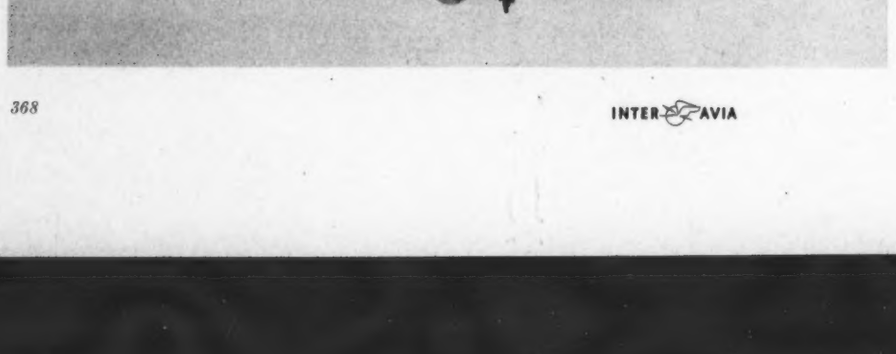
Let us first take the *airframe*. It is difficult to see how any savings could be made at the expense of its life expectancy. Any reduction in the cost of the structure will immediately compromise the safety of the aeroplane, and this already on its first flight. Things like that *have* happened when new construction materials were adopted, not to reduce the price but to cut down weight. The metallurgists are very cautious in their claims about the fatigue resistance of some of their latest creations. However, the work recently carried out in the field of plastics at the Royal Aircraft Establishment has enabled J. E. Gordon, of the RAE, to design and build a small delta-wing of "Durestos," which consists of asbestos fibres bonded with phenolic resin. Compared with similar metal structures, Durestos has superior weight, surface finish and radio permeability properties. It is cheaper to manufacture, possesses adequate mechanical strength and is easily shaped. Until recently even the best types of plastics material have been reproached for their low resistance to shocks and fatigue. Durestos is reported not to have these drawbacks. Here it should be underlined that a tendency to fatigue would not be a hazard in *consumable aircraft* provided that it does not manifest itself before the time limit of its operational life, as outlined above.

Thus, the science of engineering itself can offer solutions to the manufacturing problems it creates.

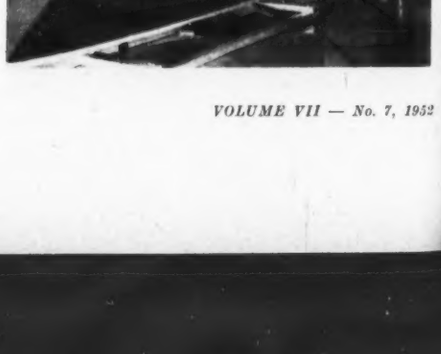
"Consumable engines" exist

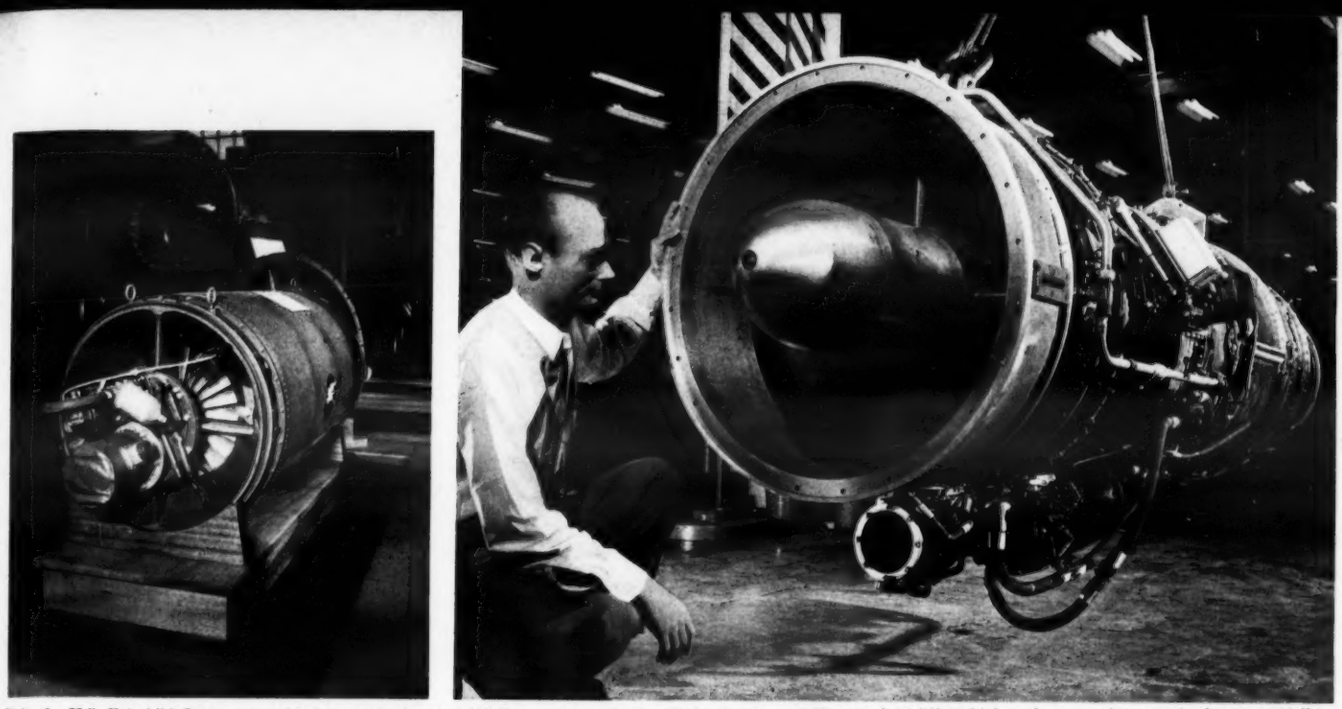
As regards "consumable engines," research seems to be ahead of that into "consumable airframes." A few years ago we put the problem of the economy of manufacturing jet engines to Air Commodore Sir Frank Whittle. The eminent pioneer gave us the following answer : "It seems to me that your aim can be attained by two means. Either you design a truly 'consumable' gas-turbine engine which could be more or less guaranteed to function normally over a limited number of flying hours. Or else—and this seems more attractive—it should be possible to use a normal jet engine in peacetime which is designed to supply a certain power and to have a certain life under optimum conditions. In the case of military operations, the same engine could be operated under overload conditions, producing a thrust 15 to 25 percent higher at the expense of its operational life ; wear and tear would be increased

Britain's Armstrong-Siddeley "Viper" short-life jet. Static thrust, 1,500 lbs.; weight, 365 lbs.



The "Durestos" plastics delta wing of the Royal Aircraft Establishment at Farnborough has a glossy, smooth surface finish.





Left, the U.S. Fairchild J-44 consumable jet : static thrust, 1,000 lbs.; weight, 325 lbs. *Right*, the General Electric J-47-GE-21 high-performance jet : static thrust, 6,500 lbs.; weight about 2,200 lbs. Cost, many times that of the J-44.

and the engine would have to be exchanged more frequently. This would mean that higher performance would be obtainable, without the need of designing and manufacturing a more powerful type."

Armstrong-Siddeley have created a true short-life gas turbine engine in the form of the "Viper" jet. The "Viper" has a static thrust of 1500 lbs., a length of 6½ feet and a diameter of 2 ft. It weighs 365 lbs. and therefore furnishes 4 lbs. static thrust per pound of weight. This power-weight ratio places it in the front rank of present-day jet engines. *Fairchild's* contribution to the same engineering problem is the *J.44*, a consumable jet engine delivering 1,000 lbs. static thrust. Owing to lack of practical experience, the price of production quantities of these engines is not available. It can be estimated, however, that their cost should be about one-sixth, per pound of thrust, of that of conventional jet engines.

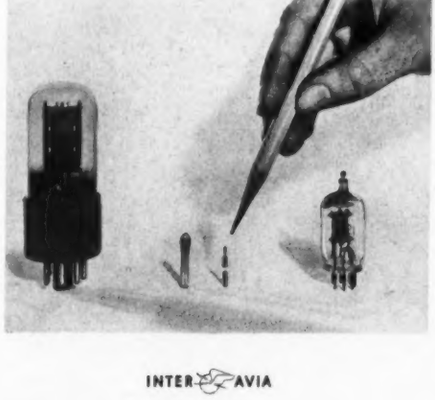
A guaranteed life of 100 operational hours and a thrust of 8,800 lbs. are quite sufficient to make such engines suitable for modern first-line aircraft. It is certain that the more frequent replacement needs resulting from greater wear would be very costly, but any analysis of the economy of such engines would have to take into account not only the lower purchase price but also the simplicity of maintenance and the possibility of reducing maintenance personnel.

The objection may now be raised that war is a state of emergency and that first-line equipment must also be able to serve for training purposes in peacetime. Nothing prevents the procurement of two types of engine, namely, consumable engines to be stored for the event of war and higher quality engines for peacetime. Upon the outbreak of hostilities the two types of power plants would be interchanged.

Simplifications and weight economies should also be possible in the case of equipment, if due regard were given to the short life of the aircraft. It is not only considerations of reliability and long life which complicate the task of the engineer but also the worry about easy maintenance and accessibility to delicate instruments. If the military users were to adapt their specifications to the actual life expectancy of a combat aircraft, the engineers would then be able to suggest a variety of simplified solutions. In the field of communications and radar detection, it is likely that the general introduction of germanium crystals and the replacement of conventional radio valves by transisters the size of a pea would greatly contribute to the simplification of airborne radio and electronics equipment. The gain would be in weight (90%), bulk (95%) and electrical energy (99%) [1]. And also in price. Here again the development of the plastics industry should sweep away all traditions, and the result be "*consumable equipment*" which could no longer be maintained or repaired but upon fulfilling its task is simply junked.

[1] It may be possible that the pilot's wireless telephone set may be stowed in one of his overall pockets in the near future and that a radar set will be reduced to the size of a pair of binoculars.

Germanium transisters replacing radio valves would reduce weight, bulk, energy requirements and cost of aircraft wireless equipment to a minimum.

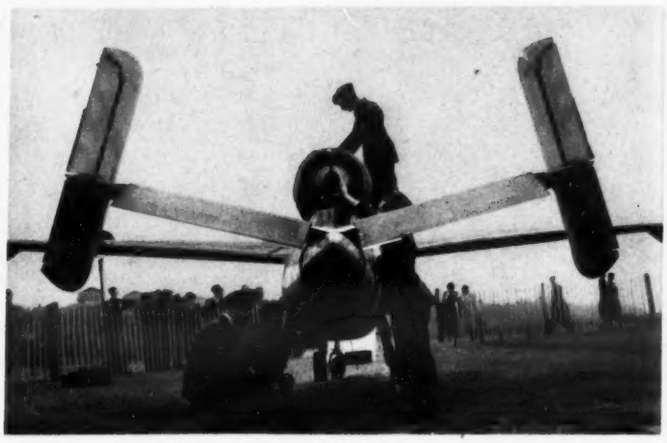


Are these novel conceptions directly applicable to any given aircraft type ? In our view, a trial could be made with short range interceptor equipment that is being talked about in Great Britain and France.

Between the luxury fighter and the anti-aircraft missile

It might have been worth while to study a little more attentively those German development tendencies which produced the Messerschmitt Me 163, the Heinkel He 162 and, even more boldly, the Bachem "Natter."

Owing to the defeat of the Nazis, the value of these projects may have been overlooked. In addition, no Anglo-Saxon General Staff would have considered it possible at the time of Germany's defeat that one day it might be necessary to cope with worries similar to those which faced the German High Command from 1943 onwards. The Russian General Staff was the only one to pay close attention to problems of short-range interception, since conventional fighters, even those of maximum range, would be incapable of providing a complete fighter screen for the vast spaces of Russia. The latest engineering results of the German war worries were passed on to the East by German technicians following the collapse of the Third Reich. The Russian General Staff made these technicians settle down to work and evolved defensive measures for the great Russian population centres. The Me 163 rocket fighter was further developed and became the Yak-21, an improved version of the Messerschmitt Me 162 was produced in quantity. In addition, a more perfected fighter of greater range was designed in the form of the MiG-15; this type, too, was based on the study of experience gathered on



Towards the end of World War II Germany developed the low-cost single-engined Heinkel He 162 "Volksjäger" short-range interceptor jet fighter. It had a wooden wing with integral fuel tanks and a metal monocoque fuselage.

this side of the Oder-Neisse Line between 1943 and the conquest of Berlin.

It is true that in Western Europe the large population and industrial centres are much more closely spaced and that as a general rule normal fighter protection should be possible. However, the transformation of the political map of Western Europe necessitates a new type of interceptor fighter to counteract the hazard of high-speed enemy bombers. This fighter should have a phenomenally high rate of climb, its design should be of extreme simplicity, especially since it would be launched by catapult and would land on a skid; in case of bad ground visibility conditions the pilot would bale out. An ultra-light fighter of this type could be produced cheaply. Range would be unnecessary, since it would be stationed in closest proximity to the target to be protected, like a falcon on a chain.

On this basis German engineers had developed an aircraft requiring only 3,000 or 4,000 man-hours of works, or about one-tenth of the time needed for conventional types. Furthermore, the conventional aircraft is much less suitable for such special missions. When World War II and Germany's need for such a type came to an end, the new development trend was still in a very early stage. If it were pursued and if the materials, power plant and armament which are available today were used in the process, much better results could be obtained.

It is easy to imagine a light aeroplane, built partly or wholly of plastics, perhaps featuring a delta wing, without landing gear, but equipped with a powerful "consumable jet." All equipment would be as simple as possible, and it would carry a whole range of rockets. It would fly at transonic speed and operate in an inverted cone of space, 50,000 ft. to 60,000 ft high and measuring about 60 miles at its base. Its take-off would be assisted by booster rockets, and it could use a water surface for take-off or landing. Or else it would alight on a skid, after having reduced its all-up weight through the consumption of the greater part of its fuel and its ammunition.

Equipment would have to include first-class sighting devices but otherwise could be limited to an absolute minimum. Indispensable would be safety equipment for the pilot, either in the form of a detachable capsule or a complete pressure suit and ejector seat permitting baling out at great altitudes.

Admittedly, the design, manufacture and operation of such an aircraft would pose all sorts of problems. Rudimentary construction is difficult to reconcile with transonic speed and stratospheric altitude. Nevertheless, the idea is practicable. Added to operational efficiency would be enormous savings in resources of all kinds, in specialized labour, repair and maintenance facilities, materials for engine and airframe. Both the last-named would be transferred to the scrap heap after a few missions.

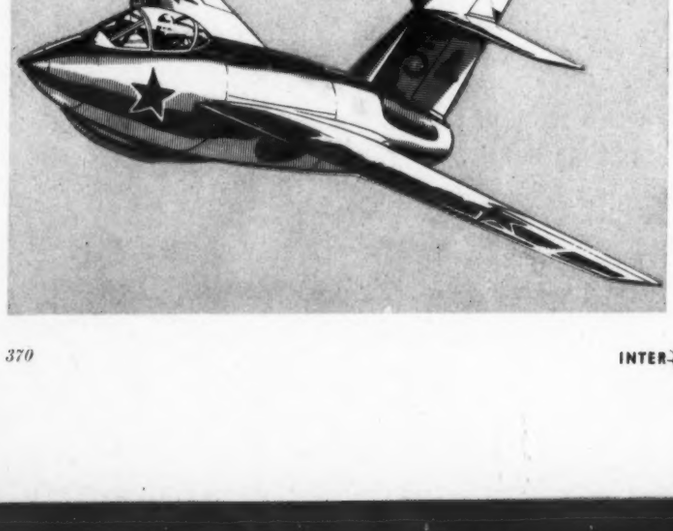
A procurement policy of this sort would free funds for other sectors of military flying, in which radical measures of economy are not possible.

*

A pilot climbing aboard one of these short-range interceptors might at first have a few qualms, for his craft would no longer be a weapon-carrying aeroplane, but merely a flying weapon. Who knows, it may even be possible to jump a stage and to exchange the "comfort of the all-weather fighter" for an air-conditioned control room in which the "pilot" is seated before a control panel guiding the course of his long-range missile.

For, in the special problem of the short-range interceptor, which is constantly becoming more complicated and expensive, at least two solutions are indicated: first the "consumable aircraft"; later on a robot deputizing for man—in other words a guided or target-seeking anti-aircraft missile.

The Soviet Yak 21 rocket-propelled short-range interceptor, derived from the well-known German Lippisch Me 163.



Two-seater night fighter version of the Russian MiG-15 jet fighter, with radar nose, heavy-calibre cannon and afterburner.

Germany's "De-Refinement Programme" in Retrospect

BY COLONEL A. ESCHENAUER, BONN

"Baka" suicide bomb of the Japanese Kamikaze corps.

The author is 46 years of age and today holds a key position in the so-called "Blank Office" at Bonn. This office is responsible for planning the rearmament of Western Germany, outlined in the Bonn Agreement of May 26th, 1952, and the Paris Treaty of May 28th, 1952, as a contribution to the European Defence Community (EDC).

Colonel Eschenauer began his career as a student of mechanical engineering and as an apprentice engineer for the Junkers Aircraft company in 1924. In 1925 he obtained his first flying licence, a little later his acrobatic flying licence. In 1933 he was appointed to the management of the German Commercial Flying School (DVS). After 1933 the DVS became the Inspectorate of Flying Training Schools at the German Air Ministry, and in 1935 Eschenauer was commissioned in the Luftwaffe. He was promoted Captain in 1936 and appointed to command a bomber squadron. In 1940 he was transferred to the General Staff with the assignment to "study equipment and modification problems of combat aircraft." When war broke out he was commanding a bomber wing. Subsequently he attended courses at the Air War Academy and was promoted. Finally, he returned to the General Staff to become chief of Division 6 (flying equipment and aircraft modifications).

This career shows that Eschenauer combines the qualifications of an engineer, an airman and an officer. While his relationship with the chiefs of the Procurement Branch of the Luftwaffe were smooth, he had difficulties with Goering and the later heads of the aerial equipment programmes (Speer and Saur).

This brief biographical note explains why INTERAVIA *requested the author to write on a subject which could be of value in view of the present rearmament effort. His professional and political career explains, furthermore, why he was given a key position in the "Blank Office" which has a good chance of becoming West Germany's Ministry of Defence in the not-too-distant future.* ED.

Technically trained air force officers of every country today are confronted with the problem of arresting the incessantly climbing curve of combat aircraft production costs.

A study of the overall cost of a modern aeroplane reveals the fact that the share of the equipment in proportion to that of airframe and power plant cost has practically been reversed in comparison to aircraft of the late war: while about 33 percent of the total cost went on equipment and about 67% on airframe and power plant, there will be aircraft in the near future in which nearly 70 percent of the cost price is spent on equipment and only about 30 percent on airframe and power plant. This reversal of proportions cannot be explained merely by the fact that modern aircraft are expected to fly at high transonic speeds and that the physical requirements are therefore much higher. The underlying cause seems to be that the technical and tactical requirements formulated by the military experts are exaggerated and necessitate the installation of a multitude of control instruments, electric and hydraulic installations which will be needed only rarely and in very special circumstances. Another factor increasing the cost no doubt is that for each type certain equipment parts have to be re-designed and installed in modified form, particularly when standardized equipment cannot be used for space or other reasons.

The German *Luftwaffe* gathered considerable experience in this field in the course of the last war, and this experience may still serve as a lesson to those who endeavour to cut the cost of modern flying equipment today.

Already during the testing of the pre-production series of a new prototype, large numbers of partly necessary and frequently quite superfluous modifications were ordered in Germany, as a result of which the original specific purpose of the type was vastly expanded even during the trial period. An army of technical experts was for ever trying to fit every single aircraft type for every conceivable mission. For example, the Junkers Ju 88 dive-bomber was given an additional electrical circuit and external racks enabling it to drop four-pound fragmentation bombs in low-flying attacks. The same aircraft also had to be capable of dive-bombing missions with two 2,200-lb. bombs or more, and it had to be able to fly low-level attacks with two torpedoes or aerial mines suspended externally. The normal radio equipment of the type reflected the peak of this branch of engineering at the time, notwithstanding the fact that the majority of these machines was used up in close-support operation. For this type of mission much cheaper or older equipment would have been perfectly adequate.

Not only did the fitting of additional internal and external equipment reduce the performance of the aeroplane, but it also led to an "over-equipment" of the machines at a time when everything began to be very scarce. The result was that a so-called *"de-refinement programme"* was initiated in the autumn of 1943. This programme was linked with a simultaneous standardization of all component parts.

The measures adopted by the Engineering Division were fully supported by the *Luftwaffe* General Staff, which ordered a reduction in the numerous sets of equipment (by providing removable sets of specialized equipment for certain missions). The industry was also aided by the fact that production models no longer had to be fully wired for specialized radar equipment; such special equipment was installed at the operational aerodromes and only in certain aircraft. If Goering had accepted some restrictions for very rare types of mission and contented himself with the original standard equipment, a lot of time, money, material and labour could have been saved.

Owing to the increasingly grim situation towards the end of the war, this de-refinement and economy programme gradually turned into a *"de-refinement mania."* The industry was asked to submit designs for so-called *"consumable aircraft"* which, in order to conceal their inferiority, were sometimes given pretty girls' names such as Elly, Wally and Nanny. It was a good thing that these designs, which were refused by the Luftwaffe General Staff and no doubt were the results of the initiative of a few party big-wigs, were never put into production. It would have been regrettable if veteran crews with hundreds of missions to their credit had been sent to their doom in such primitive machines right at the end of the war.

The principal lesson of this experience seems to be that the main purpose of a type must always be clearly kept in mind during the development period of a new aircraft. Such a policy inevitably limits the range of equipment that is required.

Another important factor lies in the ruthless distinction between those equipment items which can be operated manually and those for which electric or hydraulic operation is absolutely essential. Thus it seems superfluous to fit pressurized cockpits to aircraft whose principal mission is ground attack, just in case they *might* operate at great heights on very rare occasions. Close and respectful cooperation between the tactical and technical air force branches and the industry should produce ways and means of preventing over-refinement and thus a further increase in the cost of military aircraft.

Of cardinal importance is the consideration that this "de-refinement" should not in any circumstance impair the performance of the aircraft when carrying out its specific mission.

For European military pilots the conception of so-called expendable aircraft—which bring back to mind the **Japanese Kamikaze idea**—must be rejected **once and for all.**

Short-Life Aircraft

Genesis of the HE 162 "Volksjäger"

BY PROFESSOR ERNST HEINKEL, D.SC., PH.D., STUTTGART

The author, Dr. Ernst Heinkel, was born in 1888 at Grunbach, Württemberg. While still a student at the Stuttgart Polytechnic he built his first aircraft in 1911 and crashed in it, sustaining numerous injuries. In 1911 and 1912 he worked as a design engineer for the Johannistal Aircraft Works, near Berlin, and in 1913 he changed over to the Albatros Works at Johannistal as the company's chief designer. His aircraft won numerous competitions and prizes. In 1914 he became chief designer and technical director of the Hansa & Brandenburgische Flugzeugwerke at Brandenburg. During the first World War he created 30 different aircraft types for the Austrian Army and Navy. After the hostilities, in 1922, he founded the "Ernst Heinkel Flugzeugwerke" *at Warnemünde, which until 1945 produced about 100 civil and military aircraft types for a variety of purposes, including some designed specially for foreign countries. Amongst his creations one might mention particularly the He 70 "Blitz," the first aerodynamically efficient, fast commercial transport, which set up eight international records; the He 111 twin-engined bomber; and the He 100 fighter, which in 1939 established a world speed record of 746,606 km/h (463,92 m. p.h.). Less well-known outside Germany are the He 116, a four-engined commercial light transport; the He 176 of 1939, which was the world's first rocket-powered aircraft and flew at Peenemunde; the He 178 of 1939, the world's first gas-turbine jet aircraft; the He 280 of 1940, a twin-engined jet fighter; and the He 162 "People's Fighter" of 1944. — Dr. Heinkel in 1931 also created the catapult installations for the German Lufthansa's overseas operations; he carried out practical research work on jet propulsion from the beginning of 1936 onwards and is an honorary Doctor of Engineering of the Stuttgart Polytechnic (1925) and an honorary Ph.D. of Rostock University (1932).*

If Germany's aircraft industry arises again within the foreseeable future, there is no doubt that Dr. Heinkel will play a leading rôle in building it up. ED.

Until late in the summer of 1945 it was generally believed in Britain and America that the British Gloster E 28/39 was the world's first gas-turbine jet aircraft to fly successfully. In actual fact, however, the Heinkel 178 jet had flown experimentally as early as August, 1939. This error was excusable. Senior and even top Government officials in Germany had shown—in this case an inexcusable—"forgetfulness" regarding the success of my development work on jet-propelled aircraft.

In 1936 already I had added a gas turbine engine division to my factory at Rostock-Marienehe, which until then had engaged exclusively in the production of airframes. Two years later the first useful product emerged in the form of the HeS 3 B engine, which had a thrust of 1,100 lbs. It was ready for installation in an airframe.

I had personally financed the design and construction of our first jet engines over a period of two years—and I had kept this development "secret" from the German Air Ministry. I also sought to conceal, as long as possible, the construction of the Heinkel He 178 aircraft which had been designed specially for flight-testing the engines. I had tried to avoid unnecessary interference, which would only have slowed down my work. Interference was doubly probable because the development of jet engines should have been the duty of the engine manufacturers. This "camouflage" did not go down at all well with the people at the Air Ministry, and nobody really ever forgave me.

The He 178, the world's first jet-propelled aircraft, accomplished its maiden flight on August 24th, 1939.

The *He 178* was designed as a shoulder-wing aircraft featuring a wooden wing, a submerged gas turbine installation, a monocoque duralumin fuselage and retractable undercarriage. It had a gross weight of 4,400 lbs. and a maximum speed of 435 m.p.h. (700 km/h). On August 24th, 1939, the machine made its first flight in a straight line at the Rostock-Marienehe airfield, and on August 27th if flew its first circuits. Thus the He 178 became the first jet-propelled aircraft to fly successfully. The pilot was Captain Warsitz.

Although the two first flights were made at four o'clock in the morning, i.e., long before work began at the factory, the news gradually spread that a propellerless aircraft had flown at the Heinkel field. I therefore reported this significant event to the Air Ministry. But it was not until November 1st, 1939, that Milch, the Secretary of State at the Air Ministry, General Udet and Engineer-General Lucht came to Marienehe to watch the He 178 in flight. The demonstration made the anticipated impression, but the attitude of the observers towards jet propulsion remained cool, though not negative.

In spite of this I continued my development work. The next engine was the *HeS 8 A*, which had a maximum thrust of 1,320 lbs. It represented a considerable advance over the HeS 3 B. Thereupon I started—again on my own initiative and without the approval of the Air Ministry— design work on the *He 280 fighter*, which featured two HeS 8 A engines.

This fighter made its first flight in April 1940 and attained a speed of about 500 m.p.h. It had a nose-wheel landing gear and was armed with three 20-mm cannon. Its gross weight was 9,920 lbs. (4,500 kg), and its performance seemed to justify further development of the model for mass production purposes. However, the Air Ministry bureaucracy—with the exception of the Engineering Division—was entirely incapable of appreciating the significance of jet propulsion. In addition, the people at the Ministry refused to sanction my "headstrongness" even after the event. As a result, nobody made any positive decisions which, no doubt, would have contributed to maintaining the initial supremacy of the German Luftwaffe for a much longer period.

In spite of all this, the Air Ministry was unable to arrest further developments. Based on our experience and success, the Engineering Division ordered the BMW and Junkers companies to engage in the design of jet engines. Arado and Messerschmitt were given contracts to build the airframes. The results were the Ar 234 and Me 262. The latter was first equipped with a conventional tail-wheel landing gear but, after running into trouble, had to be redesigned for use with the type of nose-wheel undercarriage which had previously been employed in the Heinkel He 280. The waste of time resulting from this change was considerable. It was not until 1944 that the Arado

Ar 234 and Messerschmitt Me 262 went into quantity production. In view of the grim war situation at the time and the pressing need for jet fighters in the interests of an effective air defence, the time, material and equipment needed to produce the two types was excessive.

The Air Ministry quickly realised this fact and in the summer of 1944 invited a number of companies (five, I believe) to submit bids, specifications and drawings for a simple, high-performance jet fighter. Although by then I was convinced that the war was lost, I accepted this invitation for several reasons. First of all, the idea attracted me from an engineering point of view; secondly, I wanted to show the Air Ministry and the public the opportunities which they had missed by ostracizing me twice when decisive turning points in the development of fighters were being reached.

The first time was when my own He 100 fighter beat the world speed record with 463,92 m.p.h. (746,606 km/h) on March 30th, 1939. The aircraft was 50 to 60 m.p.h. faster than the swiftest German fighter then in existence. It had a wide-track, safe landing gear with wheels retracting inwards and upwards. I endeavoured to obtain a production contract, but a leading man at the Air Ministry told me in 1940: "*My dear Heinkel, we don't want two fighter types. We shall win this war with the Me 109 alone, even though it is 50 to 60 miles slower.*"

Subsequently, I was ordered by the Air Ministry to deliver most of the He 100 prototypes I had built to Russia (six) and Japan (two). A Russian test pilot flew hair-raising acrobatics in one of the machines directly after taking off. He was more than enthusiastic about the type and wrote me from Russia several months later that the He 100 was the best fighter he had ever flown.

The second time I was left out was in the case of the He 280 jet fighter of 1941.

*

And now in 1944, there was this sudden cry for a "*Volksjäger*," a "people's fighter," a type which had to be built with a minimum of material and in practically no time and which also had to be relatively easy to fly. It was specified that design, development and construction work on the experimental and pre-production types had to be completed to the point of mass production readiness within a maximum period of six months.

On September 8th, 1944, the "people's fighter" specifications were finally issued by the Air Ministry for the first time: top speed 466 m.p.h. (750 km/h) with a BMW 003 engine of 1,760 lbs. (800 kg) thrust; wing-loading not higher than 40 lbs./sq.ft. (200 kg/m²); armament, one or two 30-mm MK 108 cannon ; endurance, 20 minutes at low height; take-off within 545 yards (500 m); gross weight not more than 4,400 lbs. (2000 kg). *The whole aircraft was to be regarded as a piece of "consumer goods." Deadline : ready for mass production by January 1st, 1945.*

In April 1940, the Heinkel He 280 twin-engined jet fighter (HeS 8A engines) made its first flight. With wheels down, the aircraft is preparing to land.

It should be noted that these specifications were published on September 8th, 1944. However, no firm contract was awarded. Upon receiving these details and although I had no contract, I immediately ordered construction of a mock-up and with a large staff started work on preliminary design of the various main assemblies.

I realised that only maximum simplicity, maximum economy of time and material would succeed in getting the fighter ready in time. Production risks had to be eliminated at the design stage through the adoption of the most simple solutions. For example, it was not practicable to house the engine inside the fuselage, because this might have necessitated extensive air intake and exhaust tests, etc. The only remaining possibility was to mount the engine above the fuselage in order to reduce the hazards of belly landings.

In spite of all this simplification, the safety of the pilot was the prime consideration. We installed the Heinkel ejector seat which years earlier had proved its worth in other types, such as the He 177, the He 280 and the He 219, and had saved the lives of many pilots.

On September 23rd, two weeks after receiving the "*Volksjäger*" specifications, the first official inspection of the mock-up took place. It was attended by General Staff Engineer Lucht with a large retinue of technicians and officers and took place at Vienna-Schwechat, which at the time housed my design and engineering plant. As a result of this visit, I received the final contract on September 29th, 1944, with the following directive :

"Ref. RuK TAE No. 999718/44 geh.

Following detailed study by the Chief Development Commission for Aircraft, the Heinkel-designed single-seater single-jet miniature fighter is ordered into immediate quantity production with an initially projected output of 1,000 machines per month. Design work, detail design, testing and production will be carried out in a concentrated action as a joint project by the Government departments concerned and the manufacturers. It is agreed that, in view of the grimness of the present situation, the task can be carried out satisfactorily only by eliminating any subsequent addition of equipment or modification. It is clear, furthermore, that the method of ordering the aircraft into quantity production from the drawing board implies the risk of a failure."

A further discussion took place at the Air Ministry on October 17th, 1944. This was concerned with last-minute decisions regarding the production model and equipment. Present were representatives of the General Staff, of the Commander of the Luftwaffe's fighter formations, the Air Ministry, the research and experimental organizations, the aircraft manufacturing companies and the BMW engine firm.

Not for a moment did I underestimate the endless difficulties which had to be overcome in solving the "people's fighter" problems in the impossibly brief time that was available. I also knew that external difficulties resulting from the transport problem, material shortages and human inefficiency—especially under the effect of ceaseless bombing attacks—would become greater and more dangerous in the course of time. However, I have always been attracted by tasks offering unusual human and organizational problems resulting from pressure of time. For example, in the period from February 15th to March 31st, 1925, i.e., within about six weeks, I designed and built a night-mail aeroplane with 15 aircraft designers and three stress engineers under contract for an American firm. That was the *He 27*, for which we spent two weeks at the drawing boards and four weeks building it. Two weeks after shipping it, the He 27 regularly flew its mail routes under the name "*Night Hawk.*"

He 162 "Volksjäger" or "People's Fighter." It made its initial flight on December 6th, 1944.

Naturally, I won't deny that there is a great deal of difference between a propeller-driven aeroplane of 1925 (flying at 120 m.p.h.) and a 500 m.p.h. jet fighter to be delivered to the first-line squadrons at a rate of 1,000 machines a month. The difference lies in the scope of the project, but not in the principle.

To design and build a jet fighter in the short time available was possible only because we succeeded in firing the imagination of all our collaborators and in inducing them to turn in work which was far beyond their normal duties. Many of the engineers literally did not leave the design offices day or night for several weeks and placed mattresses next to their drawing-boards to get a few hours' sleep from time to time.

Numerous heads shared the credit for the final shape of the He 162. The Air Ministry was out to reduce the risk and forestall subsequent reproaches and criticisms. For this purpose all leading men of the German aircraft industry, the research organizations and experimental stations of the Luftwaffe were consulted on aerodynamics, strength, design and operational questions. But practically no modifications were ordered to our own design, which was the creation of my two most outstanding associates, Chief Project Engineer Günter and Chief Designer Schwärzler.

Although perfect unanimity reigned amongst those working on the project and although design work was proceeding according to schedule throughout the month of October, a certain interested party in the German aircraft industry endeavoured to interfere dangerously with our work by issuing an exhaustive "report" (October 23rd, 1944 : "An Opinion on the 'People's Fighter' Project"—"*Stellungnahme zum Projekt Volksjäger*") :

"*. . . The conception that it should be possible within six months to design, build and test an aircraft type and to put it into quantity production, although the production model will still have to incorporate test results and allow for weaknesses discovered during the testing period, surpasses my power of imagination.*"

Much less than half a year was required for the whole development work, however. Between the final contract award and the first factory flight, 69 days elapsed (September 29th to December 6th, 1944). October 30th, 1944, was the deadline for the completion of the construction blueprints. But one day before this date they had already been sent to the workshops.

These are the major characteristics of the He 162 "People's Fighter": fuselage, a light metal monocoque with a wooden nose cap moulded to shape without machining ; wings, fixed and movable surfaces of plywood; retractable nose-wheel and main landing gear. The fuel was housed in integral fuel tanks specially impregnated to make them fuel-tight. A third tank, into which the fuel flowed from the wing tanks, was in the fuselage.

Pilots were unanimous that the He 162 was easier to fly than a propeller-driven fighter. This was due to the central location of the jet engine, the absence of propeller torque, and also to the good take-off and landing qualities of the tricycle aircraft.

On December 6th, 1944, four days after the date originally fixed, the He 162 V 1 (V 1 stands for "1. Versuchsflugzeug," or experimental aircraft No. 1) made its first flight from Schwechat airport near Vienna. It lasted twelve minutes and proceeded smoothly and satisfactorily. The aircraft was flown by Captain Peter, Chief Test Pilot of Ernst Heinkel AG.

The chief of the Development Division at the Air Ministry, Engineer-General Herrmann, then sent me the following telegram : "*Our cordial congratulations on the successful flight of the 162 V 1. In recognition of this unique feat in the history of aeronautical engineering I express to you and your associates the gratitude and appreciation of the Development Division.*"

The report on the first test flight contained the following observation at the end: "Landing gear door fitting tore away. Cause: defective bonding in the wooden door."

Much greater attention should have been paid to this very dangerous occurrence. Instead of it, a demonstration flight was staged —against my warnings—on December 10th, 1944, before a large crowd of more or less important personalities who had expressly travelled to Schwechat Airport. Chief Pilot Peter thought fit to fly the machine full out at low altitude, in true aerial circus tradition. Suddenly the starboard wing leading edge ripped away owing to defective glueing, the machine shed the right aileron and wing tip. It performed several quick rolls to the right and crashed outside the airfield.

Work continued. Experimental aircraft V 2 to V 4 were complete on time, and so were the pre-production aircraft. They were tested, winter weather permitting, in December and throughout the month of January, by pilots Schuck, Francke, Bader, Wedemeyer, Bawolka and my technical assistant Meschkat in the course of numerous flights.

Characteristic of the construction of the H 162 was the fact, unprecedented in the history of aircraft manufacture, that development, pre-production series, and quantity production lines were started almost at the same time. The time interval was only two to three weeks between each stage. When the He 162 V 1 made its first factory flight, quantity production was already getting into its stride. To attain this result, two shifts were employed, the first from 6 a.m. to 6 p.m., the second from 6 p.m. to 6 a.m., weekdays and Sundays without interruption. Everything was proceeding according to this rhythm, from

Specifications for the He 162 (BMW 003 A-1 Gas Turbine)

Dimensions	
Wing area	36' 7"
Span	23' 7"
Aspect ratio	4.65
Engine	
BMW 003 A-1	
Static thrust	1760 lbs.
Thrust at 497 m.p.h. at 36,000 ft.	585 lbs.
Specific consumption	1.61 lb./lb.t.h.
Armament	
2 MK 108 30-mm cannon	
Ammunition	2 × 50
Weights	
Cannon	397 lbs.
Ammunition	128 lbs.
Armour	154 lbs.
Equipment	220 lbs.
Pilot	220 lbs.
Military load	1120 lbs.
Airframe [1]	1850 lbs.
Engine and tank	1483 lbs.
Fuel	1047 lbs.
All-up weight	5500 lbs.
Landing weight with 20 % fuel	4830 lbs.
Wing loading at landing	40.1 lbs./sq.ft.
Performance at 5500 lbs. all-up weight [2]	
Top speed at sea level	490 m.p.h.
at 19,700 ft.	522 m.p.h.
at 36,000 ft.	485 m.p.h.
Estimated endurance (full throttle)	
at sea level	20 min.
at 19,700 ft.	33 min.
at 36,000 ft.	57 min.
Estimated range (full throttle)	
at sea level	165 miles
at 19,700 ft.	267 miles
at 36,000 ft.	410 miles
Estimated maximum range [3]	440 miles
Rate of climb at medium all-up weight	
at sea level	4230 ft./min.
at 19,700 ft.	2460 ft./min.
at 36,000 ft.	690 ft./min.
Time to climb from take-off to 19,700 ft.	6.6 min.
to 36,000 ft.	20.0 min.
Service ceiling at medium gross weight	39,400 ft.
Unassisted take-off run	710 yds.
Take-off run with 2200 lbs. extra thrust	350 yds.
Landing speed (C_L = 1.45)	102 m.p.h.
Flying performance at 5950 lbs. take-off weight [2] (440 lbs. extra fuel)	
Estimated endurance (full throttle)	
at sea level	30 min.
at 36,000 ft.	85 min.
Estimated range (full throttle)	
at sea level	240 miles
at 36,000 ft.	620 miles
Unassisted take-off run	875 yds.
Take-off run with 2200 lbs. extra thrust	415 yds.

[1] With engine mount and cowling.

[2] Take-off weights do not include 230 lbs. of fuel required for taxiing, start and acceleration after take-off.

[3] Throttled back, maintaining an average height of 38,400 ft.

Mass-producing the He 162.

the reception of the production drawings to the issue of the work orders, etc. Each production stage was 100% busy day and night. The guiding principle was that no piece of paper or document should be left lying around even for a minute without action being taken. In spite of this great working pressure, everything proceeded without excitement and very smoothly.

Three final assembly plants with the following monthly capacities were planned: Heinkel-North (at Rostock), 1,000 machines; Junkers (at Dessau), 1,000 machines; and Mittelwerke GmbH, 2,000 machines per month. Heinkel-Vienna was ordered to carry out the development work, to construct the pre-production type, and gradually to integrate itself into the mass production effort with a monthly output of several hundred aircraft. For production purposes the two upper levels of the chalk-mine at Mödling, near Vienna ("Mödlinger Seen-Grotte"), well-known as a beauty-spot by excursionists, were available. In order to reduce the time interval between final assembly and combat availability, it was planned later to shift all final assembly activities directly to the operational airfields.

Metal fuselages were built by Heinkel-North at Barth, in Pomerania, by Junkers at Aschersleben and by Mittelwerke in an underground plant at Nordhausen. For the manufacture of the wooden structures (wings, tail units, etc.) two production circuits were formed: Thuringia, centering on Erfurt, and the Stuttgart area. In addition, minor wooden components for the pre-production series were made in the district of Melk-St. Pölten, in Austria. The bonding process presented certain difficulties in the initial stages. Soon, however, no more production complaints were received. The shaped, non-machined wooden fuselage nose caps were all built by the moulding specialists Behr, at Wendlingen, near Plochingen.

Although the manufacture of the wooden parts was farmed out to countless sub-contractors, including numerous artisans, it was quite surprising how precisely these components fitted together. Furthermore, the fact that quantity production at the Mittelwerke, which until then had built only V1 "buzz-bombs" and V2 rockets and which employed virtually only unskilled labour, proceeded as smoothly as at Heinkel-North and Junkers is a testimony to the simplicity of design and production methods involved, the reliability of the work drawings and production plans.

Of the tooling equipment only the master gauges, gauges and special tools for the shaping-without-cutting process were procured centrally. Apart from that, the principle of avoiding any kind of central control and administration and of permitting the individual factories to assume their own responsibility was adopted. Junkers took charge of constructing the "master fuselage" and procuring the shaping tools and gauges. The "master fuselage" was used to prepare the gauges, shaping tools and form drilling tools, which were then distributed to the individual manufacturing companies by special messengers. On the basis of the implements thus distributed, the individual manufacturers were then able to make their own manufacturing equipment.

In order to accelerate quantity production, the preparation of the tools was based on a number of destinct production stages: for the pre-production series a "divided manufacturing technique" was chosen (forward fuselage, central fuselage section, tail section, etc.); shaped parts had to be made with improvised tools (wood, zinc castings). The final stage of quantity production was planned for a "loose technique" (monocoque construction), together with shaping by cast iron tools or steel-reinforced light metal tools.

In order not to occupy unnecessary machining time, which is always in excessive demand, the first set of tools was procured from Junkers. This enabled the Heinkel works to supply all components of the manufacturing group with the necessary extruded parts. It was planned to obtain a second and third set of these tools, in order to provide each of the three main manufacturers with a complete set.

*

Even though the He 162 did not see combat service, apart from a few isolated exceptions, the fact remains that this type was made ready for mass production in a development period of only a few months—which is a peak performance in the annals of aviation history. When I was questioned about the He 162 at Farnborough in July 1945, the British refused to believe that these things had been accomplished in such a short time. They sent a mission to my factory at Jenbach to question Chief Engineer Schwärzler. The information he gave them fully coincided with that I had given them in England.

I was shown the eight He 162 fighters which had been taken to England and tested there. Very kindly I was also shown the test flight reports: they were excellent. A senior British officer stated in one of the reports that he had reached a speed of 470 m.p.h. without, however, using the full power of the machine. Flying characteristics were described as excellent and the rolls were said to be "the best in the world."

The point about the speed of the aircraft was very much appreciated by me, because the author of that same "Opinion on the 'People's Fighter' Project" submitted a memorandum to the British Air Ministry in June, 1945, in which he claimed that the He 162 had reached a maximum speed of only 348 m.p.h. (560 km/h). Since the British knew the aircraft's real speed from personal experience, they obviously recognized the purpose underlying the pamphlet. The impression was painful.

In conclusion a word of thanks to Pierre Clostermann, the French fighter pilot and author. In his excellent book, "*Le Grand Cirque*," he pays the following compliment to my 162 : "*An enchanting type, created especially for mass production, of simple design and easy to fly.*" May I be permitted to state that the "People's Fighter," or "*Volksjäger*," was not a Henschel design, as Clostermann says, but my own Heinkel 162.

I still believe that the He 162 marked a milestone in the evolution of aircraft design and particularly in the production of jet fighters, a milestone which can be considered to be of great interest even today. We succeeded in demonstrating that basically it is possible to build a high-performance miniature fighter with minimum financial and material resources.

One of the eight "Volksjäger" taken to Britain.

Short-Life Aircraft

Jet Assisted Take-off

BY THEODORE VON KÁRMÁN, PARIS

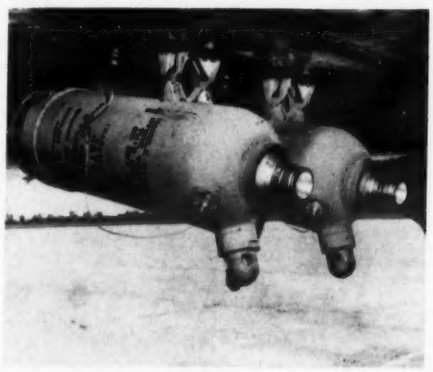
The following article by the well-known aerodynamicist, Professor Theodore von Kármán, *is more closely connected with the main theme of our issue—"Short-life Aircraft"—than might at first appear. The author was for many years in charge of rocket research at the Guggenheim Aeronautical Laboratory and is now chairman of NATO's Advisory Group for Aeronautical Research and Development. The use of JATO (jet assisted take-off rockets) enables guided missiles, ramjet fighters, and even cheaply-built rocket fighters to be employed. If take-off rockets are used, the aircraft's main engines can be designed exclusively for the requirements of climbing and cruising flight—ignoring take-off requirements—thus saving weight, fuel consumption and cost.*

EDITORS

The problem of jet assisted take-off is as old as the problem of flight itself. In fact—at least according to Admiral C. Bolster, who wrote an excellent monograph on the subject—the Chinese inventor of the thirteenth century, Wan Hah, is credited with having employed rockets to bring his wheeled vehicle up to take-off speed, whereas a number of kites which he held in each hand were supposed to take care of sustained flight after take-off. Unfortunately—according to the same source—when the rockets were ignited, Wan Hah and his kites disappeared in a blinding flash of fire and smoke. As a modern research director would say, the project failed because insufficient basic research was done and the project reached the development stage too early.

The fundamental fact which justifies jet assisted take-off—whether expressed in the design engineer's mathematical equations or in regulations issued by the CAA or some other governing body—is the disproportion which often appears between the propulsive force necessary in the take-off stage and the thrust required for cruising or even for climb and manoeuvring.

In some cases this disproportion is due to physical reasons. Consider, for example, the flying boat. In flight condition, the thrust takes care only of the air resistance, whereas before take-off the propulsion has to compensate both the hydrodynamic resistance of the body and the air resistance of the wings and the part of the structure which is in the air; yet a sufficient excess of thrust must be available for acceleration. It is known that the hydrodynamic resistance rapidly reaches a high peak in a short speed range just before the boat goes on the steps. It can also be easily seen that it is difficult to power carrier based aircraft or interceptors taking off from air-



Installation of JATO solid rockets (type 14 AS-1000) of Aerojet Engineering Corporation underneath the wings of a commercial aircraft. The rockets are electrically fired.

fields of limited dimensions in such a way that the normal thrust of their primary engines is sufficient for take-off. The advent of jet engines further increased the need and usefulness of assisted take-off. Whereas a propeller engine in a stationary aircraft as a rule delivers several times its flying thrust, the static thrust of a turbojet engine is barely greater than its flying thrust. In the ramjet engine thrust at rest is zero, and increases with increasing forward speed.

Thus it appears to be a general problem of airplane design which has to be decided in each practical case, whether it is rational and economical to determine the primary propulsive power according to requirements which prevail only during extremely short periods of the use of the aircraft.

The same problem arises on an even greater scale in launching of missiles, where the acceleration is not limited by the human element and guidance requires that the missile reaches very high speeds in a very short period of time. Thus in many cases the thrust in sustained flight is quite small in comparison with the launching or booster thrust.

The rocket engine—using solid or liquid propellant—is, of course, only one particular

A Glenn L. Martin JRM "Mars" flying boat taking off with the aid of twelve Aerojet 14 AS-1000 solid rockets.

solution of the problem. Catapult, afterburning, auxiliary turbojets are other possible solutions.

Since I myself have worked and still am working in the rocket field, I do not want to venture any opinion on the relative merits and future potentialities of the different solutions. In 1942, when I was instrumental in the formation of the Aerojet Engineering Corporation in Azusa, which is one of the few concerns engaged almost exclusively in development and production of rocket engines for assisted take-off and of boosters for missiles, I laid down certain directives for the company which I would also maintain today, after ten years: parallel development of rockets using solid and liquid fuels, nitric acid type of oxydizer for liquid rockets and composite type of powders for solid rockets with a wide range of burning speeds capable of varying thrust and duration combinations according to the specific task which the rocket designer faces.

My interest in rockets goes back to the twenties, i.e., to the time when I was teaching Aerodynamics in Germany at the Technical University in Aachen. I often listened to the talks of the good professor Oberth. I do not deny having made a few wisecracks at his expense, but I was sincerely impressed by the simple theoretical computation, which shows that the work developed by unit weight of an efficient fuel is of the same order of magnitude as the work necessary to raise the unit weight out of the sphere of influence of the earth's gravity.

It therefore seemed to me that by refined aerodynamics of rocket missiles, by use of better heat resistance materials and by clever employment of the step-rocket principle one could arrive at space travel. For the same reason I take seriously the projects of Wernher von Braun *(What are we waiting for?)* who is a follower of and successor to Prof. Oberth, although I believe that he would also be a magnificent technical adviser to Hollywood, as professor Oberth was to UFA in Berlin.

Thus, I always waited for the opportunity to do some work on rockets. When I came to the United States, teaching duties and experimental wind-tunnel and research work for more "serious" needs of practical aviation did not leave me the time for such excursions. A twofold opportunity came in 1937/38. First a group of my graduate students and some of their friends started research work on rockets on a small scale, second, General H. H. Arnold, the creator of the U.S. Air Force expressed his desire that the Guggenheim Aeronautical Laboratory under my direction should develop

Burned-out Aerojet JATO liquid rockets, used to assist take-off of a Consolidated PB2Y-5 "Coronado," being dropped after take-off. These rockets each deliver 1,540 lbs. thrust during 38 seconds.

rockets for assisted take-off of bombers. I always admired the vision and judgment of General Arnold, whose influence on the development of both military and civil aviation in the United States cannot be overestimated.

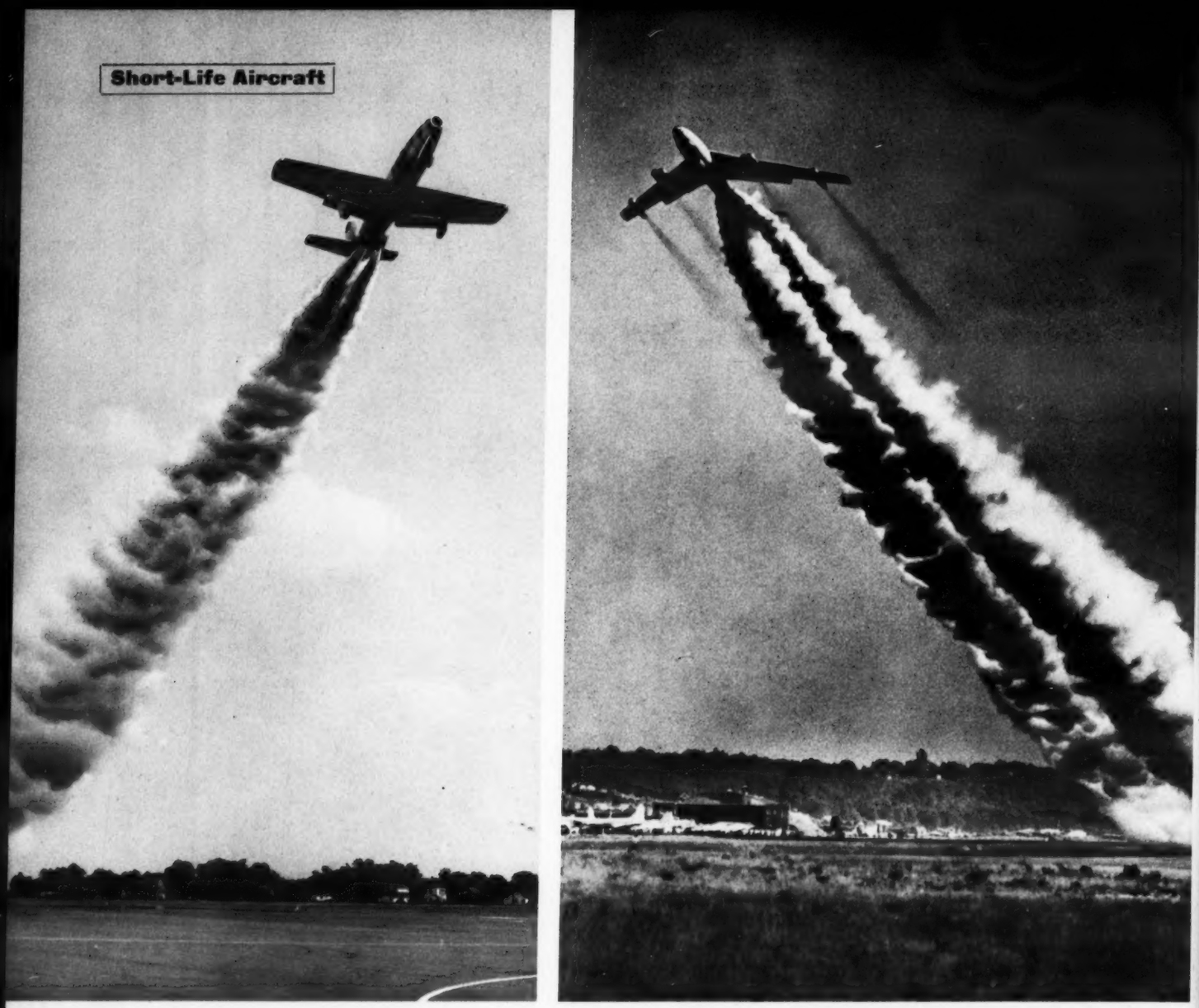
With the valuable assistance of F. J. Malina, S. S. Tsien, as well as of John Parsons and Edward Forman, we started to learn theoretically and experimentally as much as was possible on the subject of rocket engines. Shortly after, Dr. Martin Summerfield, present editor of the Journal of the American Rocket Society, joined us. The first test of assisted take-off was carried out with a small Ercoupe airplane, equipped with powder rockets. In 1941 we made a successful take-off with an A-20 Douglas bomber equipped with liquid rockets (nitric acid as oxydizer, anilin as fuel) with 1,000 lbs. thrust and 25 seconds duration, built in in the nacelles of the aircraft. In the meantime the U.S. Navy became interested in rockets and in the problem of assisted take-off. A young naval officer — R. C. Truax — was one of the leading spirits of the Navy Group. He came to the experimental station in Annapolis to the great relief of his former commanding officer on a battleship, whom he considerably annoyed by making experiments with rocket nozzles in the boiler room of his ship.

The powerful support of rocket development by the U.S. Navy Department, however, must certainly be credited to Admiral C. Bolster, then head of the ship installation branch. It is regrettable that in later phases of JATO development some "dei minorum gentium" in the Navy Department looked with a critical eye on efforts to give to JATO the prominent position in international aviation which it deserves.

As I mentioned before, the Aerojet Engineering Corporation was formed in 1942, by the group working on rockets at the so-called Galcit project. Mr. Andrew S. Haley was the company's first president. In 1944, the General Tires and Rubber Company took over the majority of Aerojet. Great credit is due to Mr. Dan A. Kimball, present secretary of the U.S. Navy for the further development of the undertaking. [1]

Compared with an internal combustion engine, or with a gas turbine or turbojet, a rocket is a very simple thing. However, very many technical problems must be solved before a really reliable and efficient rocket engine can be built. There is no other thermal engine—perhaps with the exception of nuclear piles—in which such a large amount of heat energy is produced per unit time and unit volume. Consequently the control of uniform and stable combustion involves great difficulties. In the field of solid rockets, for example for the standard JATO, the problem of the so-called "cigarette-burning" had first to be solved. In other words a cylindrical grain of composite propellant (consisting, for example, of potassium perchlorate as oxydizer and an asphalt-paraffin-oil mixture as fuel) had to be

[1] Aerojet has its main facilities for rocket development and pioneer production in its Azusa plant, which employs at present over 2,500 persons, largely engineering personnel. In addition, the company has constructed during the past year four solid propellant production lines on an 8,000 acre site near Sacramento, California. Aerojet is also one of the partners—together with Fiat and Industrie Meridionali Munizioni Affini (IMMA)—in the Compagnia Generale Italjet in Rome, which was formed for the purpose of producing JATO, forward firing rockets and other rocket devices for the benefit of friendly Western European Nations.



JATO take-off by a Republic F-84G "Thunderjet" fighter (left : four Aerojet solid rockets) and Boeing B-47 "Stratojet" bomber (right : 18 Aerojet solid rockets).

formed in such a way that the cylindrical surface is completely secured against inflammation and the cylinder burns down uniformly during several seconds in axial direction. Since then all kinds of grain designs have been studied by Aerojet and found application in solid rocket motors. A series of new propellants with increased mechanical strength and increased resistance to temperature influence were developed. The rocket has to function after being stored at extremely low or extremely high temperatures. Although the temperature influence on the burning speed cannot be eliminated completely, the variation in burning speed with temperature is considerably smaller for mixtures of chlorates and combustibles than, for example, for nitrocellulose and nitroglycerine mixtures.

Recently a rather unexpected performance of a standard JATO was accomplished in a spectacular take-off by a group of U.S. Air Force personnel under command of General Old, from an ice block called T-3, floating around about 2° off the North Pole. This group landed on the 9-mile long floating island in order to find out whether an observation post can be maintained under such conditions. As they had to take off again, the pilot declared that the take-off depended entirely on the JATO. Without JATO no take-off was possible. The crew looked at the JATO bottles attached to the airplane and found an inscription saying that no functioning was guaranteed under —10° F. The actual temperature was around —60° F. Nevertheless the JATO functioned and the group took off with some excitement but without technical difficulties.

In the development of liquid rockets a great number of novel problems face the designer. Short duration rockets can be built "pressure fed," i.e., the propellants are pressed into the thrust chamber by an inert gas under high pressure. However, for longer duration a pump system is more economical, especially in weight. The appropriate pump design is quite a problem and so is the cooling system. Furthermore, the conditions of stable burning without annoying and often dangerous oscillations is one of the fundamental problems of combustion theory. There are several reasons for so-called self-excited oscillations. The propellant injected in the rocket chamber traverses the chamber in an extremely short period of time. If the lag in the evaporation and combustion process is of the same order of magnitude as the "residence time" of the propellant in the chamber, oscillations can develop which make the rocket useless for practical purposes. There are resonances possible with the feeding

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system, with the acoustical vibrations of the hot gases in the chamber, etc. All these difficulties have been overcome step by step and we have reliable liquid rocket engines both working with so-called "hypergolic" fuels (i.e., fuels which ignite instantaneously when they are brought in touch with an oxydizer) and fuels which need ignition like those used in ordinary jet engines.

Jet assisted take-off has both military and civilian applications ; JATO has been tested practically on all types of U.S. military aircraft. The number of units ranges from one, as on the F_4 F_3 naval aircraft, to eighteen on the Air Force B 47 bomber. (Boeing "Stratojet" with swept-back wings).

The operation of modern day carrier-based fighter aircraft presents many opportunities for the advantageous use of JATO. JATO may be employed to reduce the take-off interval and thus enable a carrier's complement of aircraft to get into combat or off the deck appreciably quicker. In the event of catapult damage or failure of the catapult, JATO provides a means of continuing operation.

Under adverse wind conditions or when damaged carriers cannot attain the speed necessary for normal aircraft launching, again JATO provides a means of operating. When the forward take-off areas of the deck have been damaged there have been instances where the airplanes were spotted toward the aft section of the flight deck and took off to the rear aided by JATO.

During World War II the JATO motor was responsible for the saving of thousands of lives when used on rescue aircraft. Rescue missions flown from restricted areas, high altitudes, fields or rough seas became routine by the application of JATO. Rocket motors, especially those with liquid fuel, are also successfully used for super-performance of jet planes. They increase the rate of climb and manoeuvre speed for a limited time. This increase, however, may be a deciding factor in high altitude combat.

The Aerojet 14 AS 1000 was certificated as the R.1 by the Civil Aeronautics Administration and is as yet the only rocket motor certified for use on commercial aircraft.

Its introduction for general use is, however, still in an early stage. The jet assisted take-off has extraordinary advantages or is almost a necessary condition for successful operation in fields at high altitude and in short fields. Thus Braniff International Airways states that they are able to carry twenty additional passengers in their operations out of La Paz, Bolivia, when using JATO. Pan American Grace Airways admit that they would operate at a considerable economic loss if they did not use JATO at the same location.

Certain important safety factors are provided by JATO on multi-engine aircraft. Assuming an engine failure beyond the point on the runway where the pilot is committed to take-off, the availability of JATO of the proper configuration will enable the pilot to feather the inoperative engine, retract the landing gear, reduce take-off flap setting and eliminate other items of drag during the duration of JATO thrust. When these items of drag are eliminated, it will be possible for the airplane to maintain altitude for sufficient time to insure a safe landing.

I have no doubt that after the solution of some minor technological problems JATO will also serve as an accepted stand-by to give the pilot additional thrust in an emergency.

Two Aerojet JATO liquid rockets increase the thrust of the North American B-45 "Tornado's" four J-47 jet engines by 8,000 lbs.

The U.S. Navy's Douglas D-558-2 "Skyrocket" experimental aircraft (J-34 jet engine plus Reaction Motors rocket engine) taking off with the aid of two jettisonable Aerojet 14 AS-1000 solid rockets.

Short-Life Aircraft

Just why are Aircraft so Costly?

BY "BOFFIN," LONDON

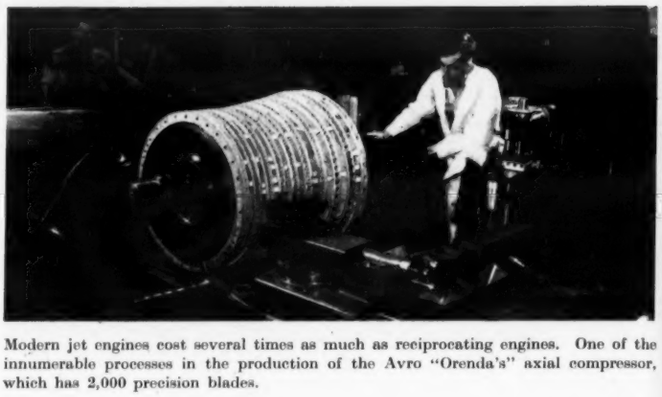
The way in which the price of aeroplanes of all kinds has risen in the last ten years is a problem that has alarmed many in the industry—but little has been done to arrest the steepening trend of the cost curve. Military aircraft are the worst offenders—they always have been, because no expense is spared to achieve superiority. Any study of the causes of the excessive rise in price is hampered by the secrecy that enshrouds the military product.

The first approach to the subject is to have a look at the general position. World War II, just as did the first World War, greatly reduced the value of money. The result of this is that even a training aeroplane today costs much more than it did before the war.

Before the war the high-wing, 3/4 seater tourer-trainer of the "Auster" variety cost about £500. Today the figure is £1,200. This rise is for a machine made on jigs already paid for by a military contract. The all-metal "Chipmunk" elementary trainer costs something like £2,400, even produced by the hundred, as compared with less than £1,000 for the simpler "Tiger Moth." Basic trainers in the 250 h.p. class, such as the Fokker "Instructor," cost about £5,000—the price of a pre-war "Spitfire" airframe.

The rise in cost of two-and-a-half times for the British aircraft compares with general increases in living in Great Britain and it reflects fairly accurately the rise in wages of the aeronautical and raw material worker. The comparison of the "Tiger Moth" and the "Chipmunk" shows how the price of a more advanced design built by improved methods can be kept on the same cost curve if the production planning is good.

The purely military aeroplane has, however, run right away from the anticipated cost curve to be deduced from general wage and price rises. A heavy item in the price of a fighter, for example, has always been its engine. The famous Rolls-Royce Merlin cost around £2,000 at the beginning of the war. That money bought half-a-ton of complex, finely made machinery and it was to be expected that the far lighter and much simpler jet engine would be a great deal cheaper. Not a bit of it: even the relatively simple centrifugal is dearer, while the complicated high-powered axial is several times as expensive.



Modern jet engines cost several times as much as reciprocating engines. One of the innumerable processes in the production of the Avro "Orenda's" axial compressor, which has 2,000 precision blades.

A recent British Government document provided some interesting figures for aeroplane costs.[1] Unfortunately, although the aeroplanes were divided up by classes, actual type names were not given. Nor was it made clear how fully equipped the examples were supposed to be (airframes without engines?); one presumes that they were production models *without specialized military equipment.*

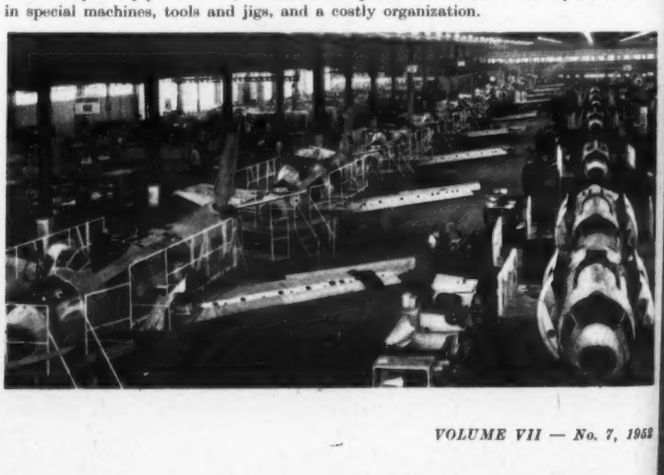
Types	*Feb. 1945*	*Feb. 1951*	*Latest Figure*
General reconnaissance	£44,845	£105,055	£114,695
Air observation post	1,090	2,875	2,890
Fighter	9,680	16,160	16,720
Light bomber	15,915	77,600	89,105
Transport	45,240	91,395	91,550
Elementary Trainer	1,100	3,120	3,220

Save for the aeroplanes one supposes to be the "Canberra" and the "Meteor," this table does not seem to include any jets, and the "Meteor" is hardly comparable with a sonic-range fighter with its multitude of

[1] *The Second Report from the Select Committee on Estimates, 1951-1952,* published February 25th, 1952, by H. M. Stationery Office.

The building of prototypes (Hawker P.1081 jet fighter) takes highly skilled hand work . . .

. . . while quantity production (Canadair's F-86 production line) needs heavy investment in special machines, tools and jigs, and a costly organization.



special requirements. It is *very* important to realise that the prices for the service aircraft are vague and no explanation has been given about "embodiment loan" items. These are instruments and equipment supplied to manufacturers from government stores and which are therefore not included in the cost of the aeroplane.

Another point is the financing of prototypes. In the case of military aeroplanes built to a specification all design, development and test work is paid for by the Government. If a type is accepted, the Ministry of Supply then pays for a batch of *x* aeroplanes at a price that covers tooling as well as manufacture and allows the firm a fair profit on its turnover—so that the price of individual aircraft in a subsequent batch is likely to be lower. If a military aeroplane is sold abroad it is liable to a government levy toward the development and tooling costs.

*

Far exceeding the high cost of modern aeroplanes in Great Britain are the astronomical prices in the USA and Canada. A clear overall picture here is also impossible because of the security veil, but here and there a tear allows one to glimpse something of the golden cascade behind. Tooling alone for the B-36 is said to have cost something like $80,000,000, while the man-hours, originally 225,000, are still 175,000. This means something like $350,000 to $450,000 on labour alone. Fighters, it has been said, today require something like 22 man-hours per pound weight.

Most shattering cost figure of all was that recently admitted by the Canadian Department of Defense for the *North American F-86 "Sabres"* being built under licence by Canadair. An average figure of $234,000 for the airframe plus $78,400 for the engine and normal flying equipment.[2] A curious feature of this is that the J-47 jet engine is priced at a little under $50,000 ; which seems an appalling figure where a production run of around 15,000 will have been completed by next summer.

*

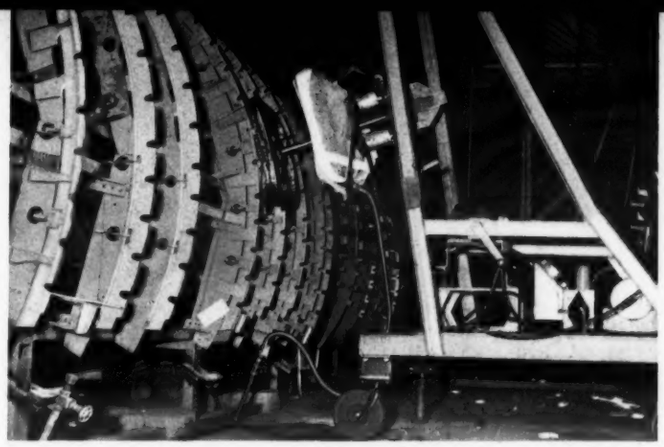
Quite frankly, this seems incredible to the writer, who has seen the highly efficient Canadair production line in full swing. Nevertheless, it has been admitted in black and white and it is of some interest to try and see where the money goes.

First contributory cause of high cost is, of course, the high wages on the other side of the Atlantic: an average in Canada of $1.50 an hour against, for example, 3 shillings (or 38 cents) in Great Britain.

The outstanding cause of the "Sabre's" expensiveness is, of course, its high degree of refinement to obtain high speed and high altitude. Although in essence a conventional structure, high performance has led to intricate and costly detail design. The thin wing, for example, must have a thick machined skin. Although such a skin requires fewer stiffeners, its manufacture on the skin taper mill is expensive in machine time. The special machine, the still comparatively rare *Cincinnati Hypro Taper Mill,* is a costly tool.

F-86 manufacture is broken down into many sub-assemblies—rather more than in European practice. As an example, the front fuselage (or cockpit section) is built on to the air intake duct and apart from the jig for that part itself, the unit is built up on no less than eight jigs *before* it reaches the travelling fuselage line where all plumbing is fitted before it is mated with the rear fuselage. Such multiple jigging and breakdown usually pays off on long runs.

[2] *Editor's Note:* The total price of $312,400 for a Canadair-built "Sabre" is exclusive of military equipment and merely comprises normal flying equipment. A combat-ready "Sabre" fighter of the "simplest" variety is reported to cost $430,000, whereas more advanced models with full radar equipment, etc., are understood to cost about $550,000 each. In other words, airframe and engine, costing $284,000, account for only about 51% of the fully equipped combat aircraft of the latest version.



Metal bonding (jig for de Havilland Comet window frames) reduces production costs and weight.

The final assembly line, from the time the fuselage and wing are joined, takes twelve stages, and one would guess that something not far short of 1,000 man-hours are involved. During this progress all systems are checked functionally *three times* and even when the "Sabre" leaves the assembly hall it has a further series of functional checks and inspections before, between, and after test flights—including even a full 50-hour servicing schedule.

Reason for the meticulous checking is the all-mechanical nature of the "Sabre"; the power-operated controls, with their elaborate mechanical linkages, delicate control valves with 0.0005 in. tolerances on dimensions, and hydraulic operating rams, all these are heavy cost raisers. Everything must be in working order in these "robot" fighters, because with system failure the pilot often has no choice but to bale out.

All this serves to show where the money goes qualitatively if not quantitatively. Compared with the "Spitfire," or even the "Vampire," the "Sabre" is almost as complex as a multi-engined bomber, even though it is less than a quarter the size.

*

In what way, then, can money be saved in the making of modern military aeroplanes? The position is not very hopeful.

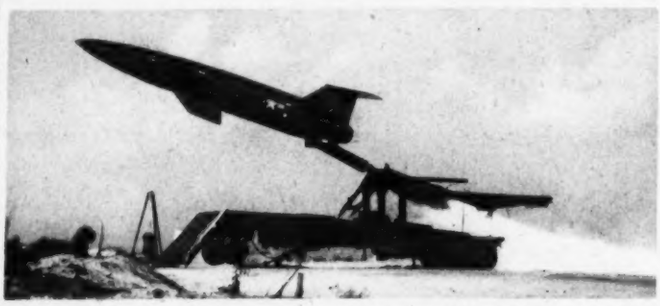
The airframe can certainly be made less expensively in more ways than one. One expert has said that structures can be made for little more than half the price by using *plastics-bonding instead of rivets*—which also has the advantage of reducing weight.

Some people, notably at the Royal Aircraft Establishment, Farnborough, believe that a solution lies in the all-plastic wing. They have made an *experimental delta wing from "Durestos,"* which consists of asbestos fibre bonded with phenolic resin. This, however, is a laboratory experiment and the unit is no larger than a moderate-sized tail plane. Furthermore, it was moulded as a single piece, a most unpractical arrangement for any service aeroplane. Other doubts arise about the weathering properties of such a structure, for plastic radomes erode badly in a single rainstorm. Repair, too, would be a problem requiring very special equipment, including heating and pressure elements. Here again the effects of heating by skin friction at high speed would be serious and would certainly reduce strength.

Furthermore, although the plastic wing has possibilities where a true "lobster claw" is required, the material would, one imagines, be incapable of sustaining the high concentrated stresses of, say, the undercarriage when landing at 150 m.p.h. Another drawback may be the making of large units in moulds, for this would make it very difficult to incorporate modifications—and a military aeroplane without modifications is like a bull without its horns ! It is early days yet to

Ancestors of the "Expendable Aircraft"

Manned—or rather "womaned" (pilot was Hannah Reitsch)—prototype of the German VI flying bomb, with pulse-jet engine. The pilot's seat was fitted only for test purposes.



Martin B-61 "Matador" remote-controlled tactical robot bomber (jet gine plus take-off rockets) leaving its launching ramp.

Manned German expendable fighter, the Bachem "Natter," was armed with 24 or 48 rockets of 73 mm calibre.

prophesy, but there are very many snags in the plastic aeroplane and, whatever it may be in the future, it is not an immediate answer to aeroplane cost.

*

Another approach to the problem lies in the short-life and the expendable aeroplane.

First of all, the *short-life aeroplane.* Statisticians discovered that in the last war the average life of a fighter was fifty hours, that of a bomber less than a hundred. From this arose the idea of designing cheaper aeroplanes built only to last for 100 hours, and to require no attention other than greasing and refuelling. As an ideal this was excellent but it is not practical. First it means throwing out those aeroplanes that reach 100 hours, secondly it means restricting practice flying, thirdly even if the scheme were to work in wartime it would be a burden in peacetime.

In any case, the equipment and instruments—where up to 50 or even 60 percent of the expense goes—are the same and it is difficult to make short-life precision parts more cheaply than long-life ones. Attempts were made in Britain to evolve such a fighter, but the scheme fell through because the troubles were far greater than the saving likely to be effected. Royal Air Force policy today is to produce airframes, engines and equipment which are of such good design and workmanship that they will need the minimum of maintenance and so save man-hours and money in that way.

The *expendable fighter or bomber* is a new conception. The Americans have already an operational unit using the Martin "Matador." Here you have an elaboration of the German V 1, plus some additional (and expensive) radio for guiding. The airframe, though, is simpler, much smaller and cheaper than a manned bomber capable of carrying the same load. There is no doubt about that fact ; but will the manned bomber really make insufficient trips to offset this, and will the guided missile be as accurate ? Once again, the outsider has no means of judging.

The so-called *expendable fighter* is a conception on the lines of the German BP-20 Bachem "Natter," a product of the last days of the war. The small, wooden mid-wing single-seater had a span of 12 feet, was powered by a Walter rocket motor and took off with the assistance of booster rockets from vertical rails. Guided to a "target-point" by radio, the pilot was to make his final sighting adjustments and fire his single "broadside" of ammunition on the bomber. Thereupon the pilot was to bale out and the "Natter" crash to earth. In effect, it was a guided missile with a pilot to finish the job.

This seems a very fallacious idea for several reasons : first of all, the fighter must have instruments and guiding radar (or radio guides) if it is to do its job, and all this is expendable; next, the airframe will have to be accurately made for high speed and must have powered controls for manoeuvring successfully ; and, finally, since interception is often over one's own country, the hazards of falling aircraft will be increased. It does, in fact, seem that the expendable-fighter would be a much less effective weapon, and a more costly one, than a good guided missile—like so many compromises it falls between the two effective extremes.

*

To sum up, it seems there is little hope of reducing the cost of military aeroplanes. The demands of high-speed aerodynamics and the stresses of high-speed flight require an expensive airframe ; flight at high speeds and great altitudes means air conditioning and pressurizations or at least pressure suits; the immense powers required for sonic flight demand expensive, highly-refined engines; high landing speeds mean strong, precision landing gear; military requirements mean all-weather radar and more radar for searching, gun-aiming and bomb-aiming.

In other words, it is the duty of the aircraft that dictates its equipment, sends up the size, the weight and the cost.

Seventeen transports can be counted in the loading ramp areas in this unusual night photo taken recently at Los Angeles International Airport. Note trace of plane lights in background during take-off.

The Japanese "Air Girls" are back!

Japan's post-war air carrier, which inaugurated its services towards the end of last year, is again employing air hostesses—after a time interval of almost exactly ten years.

It was in September, 1941, three months before Pearl Harbour, that the Japanese military authorities prohibited the employment of female crew members aboard aircraft, thus putting an end to a ten-year old tradition.

Twenty years ago, in 1931, Japan's first stewardesses became part of the regular crews of commercial aircraft of the Tokyo Air Transport Co. The company flew the domestic route from Tokyo to Shimoda and Shimizu. The flying distance was short (barely 125 miles), the aircraft were single-engined machines carrying four or five passengers, and the services of the hostesses were hardly needed. However, the "air girls" were considered to be an excellent advertisement for the company's operations.

The Japanese "come hither" look. Note the built-in passenger steps of the DC-3, a practice widely used on this type of aircraft operating on feeder routes in the USA.

JAL's fifteen air hostesses, lined up in front of a DC-3.

In 1938 Japan's national airline, Dai Nippon Koku Kabushiki Kaisha, introduced Douglas DC-2 and Lockheed 14 twin-engined types on its routes from Tokyo to Osaka, Fukuoka, Seoul, Wiji and Dairen. It was on these aircraft that the Japanese air hostesses really justified their existence. Another company, Manchuria Aviation Co., introduced the twin-engined Junkers Ju 86 on its main route from Dairen to Mukden, Changchu and Harbin, and here again the hostesses were found to be indispensable components of the crews.

In September, 1941, their employment was forbidden, and they remained "grounded" until the inauguration of the new services by Japan Airlines Co. (JAL) on October 25th, 1951.

So far, JAL has chosen and trained 15 girls from over 1,000 applicants. The company, which for the time being operates aircraft chartered from Northwest Airlines and Philippine Air Lines, expects to open several international air routes in the near future, and it will be on these routes that the "air girls" will come into their own. The Japanese hostesses have indeed proved to be very popular among foreign tourists, and one airline, Thai Airways Co., has invited several Japanese stewardesses to serve aboard its aircraft.

JAL's "air girls" are being honoured by an "inspection" by Mrs. Ridgeway, wife of General Matt Ridgeway, until recently U.S. High Commissioner in Japan and C.-in-C. of U.N. forces in Korea, now the successor to General Eisenhower at SHAPE in Paris. At left is Aiichiro Fujiyama, Managing Director of JAL and one of Japan's leading industrialists.

Book Reviews

Glossary of Aeronautical Terms. Published by the British Standards Institution (Part 1 : 1950 ; Part 2 : 1949 ; Part 3 : 1951).

Although it is some months since Part 3 of this aeronautical reference book was published, it is perhaps still not too late to write an appreciation of it. These three volumes are not only indispensable to the beginner, but also of immense assistance to the expert. Arranged under subject headings (theory of flight, aircraft and engine structures, accessories, maintenance, air traffic organization, radio, meteorology, etc.) all current aeronautical terms, as well as others newly-coined and less well known, are defined and explained briefly and concisely. Wherever required the text is supplemented by readily understandable sketches, formulas, symbols, meteorological tables, etc. The Glossary provides a valuable time-saving aid for all who have to work with English aeronautical terms. *Ba.*

Books received

Publications scientifiques et techniques du Ministère de l'Air. — Distributed by Service de documentation et d'information techniques de l'Aéronautique, Paris :

No. 258. *Calcul de la couche limite compressible — Applications pratiques élémentaires des méthodes Oswatitsch-Walz et Gruschwitz-Walz,* by Adalbert Oudart.

No. 259. *Séries de Fourier régularité, séries divergentes et formulation expérimentale,* by Pierre Vernotte.

Publications of the International Civil Aviation Organization. — Published by ICAO (in English, French and Spanish), Montreal, 1952.

Dimensional Units to be used in Air-Ground Communications (International Standards and Recommended Practices) ; Annex 5 (second edition) to the Convention on International Civil Aviation.

Operation of Aircraft : International Commercial Air Transport (International Standards and Recommended Practices) ; Annex 6 (third edition) to the Convention on International Civil Aviation.

Air Traffic Service (International Standards and Recommended Practices) ; Annex 11 (second edition) to the Convention on International Civil Aviation.

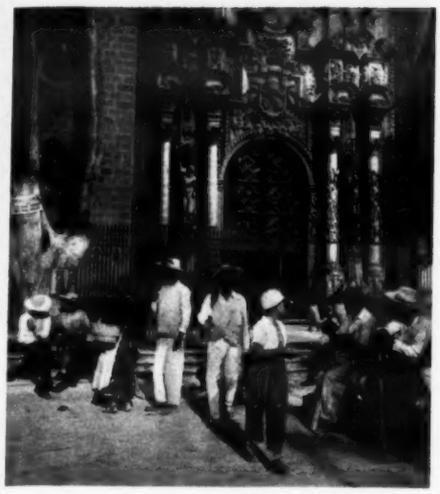
Radio-Electric Storm Detection (Sferics), Circular 22-AN/19.

Aircraft Accident Digest No. 2. Circular 24-AN/21.

Runway Design Methods for Multiple Wheel Landing Gears, Circular 25-AN/22.

Mexico, the Airlines' Paradise

BY GEORGES FÉVRIER, INTERAVIA'S REPRESENTATIVE IN FRANCE



Paseo de la Reforma, Mexico City.

I have long since ceased counting the number of hours I have flown . . . and yet the lure of distant lands is still upon me, and an invitation to go somewhere new never falls on deaf ears.

And yet what can an aviation journalist find to say nowadays about an air trip ? After all, the Atlantic looks pretty much the same all over from a height of 18,000 ft.

All this went through my mind as I packed my bags—the usual 66 lbs., not counting my over-night bag. But Air France was "inaugurating" Mexico City, a new territory for me, with sunshine, colour and music . . . How could I resist such a trip ?

The blue and silver Constellation looked rather like one of the drawing rooms at the Elysée Palace, during a reception. Max Hymans, President of Air France, was receiving, assisted by Louis Costa de Beauregard and the flight captain, Max Castello. His guests were Guy Petit, Cabinet member, representing the French Government ; two former Prime Ministers, Paul Reynaud and Jules Moch ; René Lemaire, Secretary General for Civil Aviation ; Louis Joxe, French Ambassador to Moscow ; F. Jimenez O'Farril, Mexico's Ambassador to Paris, etc. The only person missing was Vincent Auriol himself . . .

But, like modern apartments, this drawing room, too, had to serve many different purposes. As far as Shannon it was a luxury restaurant, with caviar, foie gras and Mumm 45. Between Ireland and Newfoundland it was transformed into a comfortable bedroom for 34 persons, thanks to the convertible reclining chairs. And on the last leg to New York it finally took on the aspect of the breakfast room of a classic American hotel.

No, the great Atlantic has not changed. Nor has New York Airport or, alas, its Customs and Police services. But what did I care for the Yankee officials, with their questions and counter-questions ; I was going to MEXICO !

In New York we got a new crew and were joined by Air France's "American Staff," Henri Lesieur, general representative for the United States and the Caribbean ; Paul Besson, technical director ; Pierre Roussel, commercial director ; Victor Raeburn, P.R.O. . . .

And now the aircraft—the first scheduled European service to do so—is flying south over Virginia, North and South Carolina, Georgia . . . Atlanta and the ghost of Scarlett O'Hara, New Orleans, the Mississippi and its great Delta, dear to the heart of Louis Bromfield, the Gulf of Mexico, Tampico *(very near from Mexico . . . a nice place to go,* says the song). Soon the hills round Mexico City appeared, then "Mexico Central" airport, with thronging crowds, Mexican music and gaily-coloured flags. The first Paris—Mexico City flight was over ! With its non-stop trip from New York to Mexico City in eight hours five minutes, Air France's Constellation had cut four hours off the normal time between the two capitals.

Once more I felt the magic of an air trip to a far-off country. What a long way I had come from Notre Dame to Paseo de la Reforma, with its market stalls, sellers of lottery tickets, picturesque beggars, Indians in tall hats and music—everywhere music.

A country made for flying

Watching the constant stream of DC-6s, DC-4s, Constellations arriving and departing—there are more aircraft movements at Mexico Central than there are at London Airport—I was joined by Agustin Garcia Lopez, Secretary of State for Communications and Public Works, who told me :

"Mexico is made for flying. You ought to talk to Angel Martin Perez . . ." I couldn't have found anyone better to introduce me than my old friend Henri Lesieur. Hadn't he negotiated with him all the Franco-Mexican agreements ?

Don Angel received me on the tenth floor of the skyscraper which houses the Civil Aviation Department, at 28 Aquiles Serdan . . .

"In spite of its thousand-year civilization," he said, "Mexico is a new country. Unlike the old countries of Europe, it is not strangled by a close road and rail network. In spite of its mountainous and volcanic countryside, it is the ideal country for flying because the weather is nearly always good. And although it is not too easy to build airports and runways, it is still a good deal easier than building roads and railways, with the endless bridges and embankments they need everywhere in this country. So we formed, back in 1920, a technical air navigation section, which became, eight years

"Like a reception at the Elysée Palace." On board Air France's Constellation : President Max Hymans (standing, left) talking to (left to right) Paul Reynaud, Guy Petit and Jules Moch.

Mexico Central's control tower.

later, the present Department of Civil Aviation, attached to the Secretariat of Communications and Public Works.

"Our network at that time was not a close one. Look at the map. Apart from the Mexico City—Queretaro—San Luis Potosi—Saltillo-N. Laredo federal service, we had services between Mexico City and the United States, via Tampico, between Mexico City and Cuba, etc. Altogether a route mileage of 4,000 to 5,000 miles.

"Today, we have a network of 32,900 miles, or, counting all the "concession" routes, nearly 100,000 miles. Thirty-five airlines—29 national and 6 international—made over 65,000 flights between them last year.

"Just glance at this table and you will see for yourself what progress we are making.

The new Air France office in Mexico City.

	1949-1950	*1950-1951*
No. of flights	49,645	66,566
Km. flown	38,209,139	46,821,010
Hours of flight	151,656	174,460
Passengers	882,847	1,128,385
Mail (kg)	1,996,208	2,416,216
Express (kg)	24,225,628	22,055,168
Freight (kg)	6,470,888	7,165,888
Baggage (kg)	6,572,898	18,269,859
Air mail parcels	96,401	181,184

"What are the foreign airlines that operate to Mexico ?"

"Under bilateral agreements—Mexico is a member of ICAO and our Enrique M. Loseza is a member of the Council—Pan American Airways, American Airlines, TACA International Airlines, Aerovia "Q" and, now, Air France have received the necessary authorizations. From October onwards KLM will be able to operate between Amsterdam, Montreal and Mexico City. We are also in discussion with BOAC, SAS and Trans Canada Air Lines.

"In return, some of our Mexican airlines run services to other countries ; for example Compania Mexicana de Aviacion S. A. (to Havana, Cuba and the United States), Lineas Aereas Mexicanas (to San Diego, San Antonio and Houston), Transportes Aereos Mexicanos (to British Honduras), Compania Aerotransportes S. A. (to Brownsville), Aerovias Guest (to Miami). Before the agreement with Spain was cancelled Aerovias Guest also flew to Madrid . . . and Iberia came to Mexico City. However, there may soon be flights to Europe again, to Lisbon, Paris and perhaps to Zurich.

"What about your domestic services ?"

"All routes are 'concessions' granted after a trial period to individuals or companies, in accordance with our Mexican air law, of Mexican nationality. Like the international airlines, Mexican companies are formally obliged to use the air traffic control services. Up to 1946 each company was responsible for its own ground services, but since then these have been provided by RAMSA (Radio Aeronautica Mexicana S. A.), a non-profit organization working on concession from the Secretariat for Communications and Public Works. Each airline pays RAMSA a fee according to the services it receives.

"In addition to the passenger airlines, there are also pure freight companies. We give special permits for the carriage of vegetables and . . . shrimps (between Ciudad del Carmen and Campeche for Brownsville, New Orleans and Miami), and for agricultural work.

"However, I feel that the number of companies is too high, and we are trying to get them to group together a little more. All co-ordination and unification work is the responsibility of the Secretariat for Communications and Public Works."

Mexico central is ready for jets

"A word now on the airports. Mexico Central, as you have seen, leaves nothing to be desired. In spite of its altitude (7,550 ft.), its 3,500-yard runway is long enough to take commercial jet aircraft—when they come ! The other runway, 2,450 yds. long, is fully adequate for all present-day aircraft. The construction of the landing area cost over three million dollars, thanks to the extensive draining work required, and the terminal building, which is to be 990 ft. long and 135 ft. wide and is already well advanced, will itself cost almost another million. We are also planning to instal GCA and ILS in the near future.

"At the same time we shall improve the installations at Toluca, Mexico Central's natural alternative.

"Outside the Federal District we have built or improved 14 aerodromes during the past two years, and within the next three years we hope to be able to open 50 new first-class airports.

Don Angel Martin Perez, Director General of Mexican Civil Aviation.

"The Directorate of Civil Aviation runs search and rescue centres and three large schools. The first two, Institut Aero Nacional and Escuela Nacional de Aviacion, which operate at the central airport, also take pupils from Central America and Colombia. The third, Escuela Civil de Aviacion 'Cinco de Mayo', at Puebla, has only Mexican pupils. Finally, in October, a training centre for ground personnel for the whole Caribbean area is to be opened at Mexico Central, under ICAO auspices.

"Now," concluded Don Angel Martin Perez, "I should like to ask you a question. If ICAO leaves Montreal, do you think Mexico City could bid for it to come here ?"

But that was a question which I didn't feel I could answer.

Personnel licenced

The Schools and Technical Personnel Section has awarded the following licences since its foundation :

Flight personnel	
Private pilots	2,338
Commercial pilots	1,396
Public transport pilots	356
Navigators	5
Ground personnel	
Mechanics	2,279
Mechanic's apprentices	1,190
Control tower operators	2
Control tower assistants	72
Air traffic supervisors	70
Airport managers	89
Medical officers	4

The major airports

	Runway length
Mexico Central	3,500 and 2,450 yds.
Guadalajara	2,400 and 1,970 yds.
Nogales	2,080 yds.
Ciudad Juarez	1,910 yds.
Mazatlan	1,790 yds.
Leon	1,750 and 1,090 yds.
Tepic	1,680 yds.
Veracruz	1,670 and 1,640 yds.
Acapulco	1,640 yds.
Torreon	1,640 and 1,520 yds.
Tijuana	1,670 yds.
Parral	1,480 and 1,310 yds.
Morella	1,530 yds.
San Luis Potosi	1,310 and 1,090 yds.
Zihuat Tanejo	1,090 yds.

The terminal building under construction at Mexico Central (990 ft. long).

List of Airlines registered in Mexico (1950)

National Airlines

(Passengers, mail and freight)

AEROTRANSPORTES S. A.
AERONAVES DE MEXICO, S. A.
AERONAVES DE OAXACA
AERONAVES MICHOACAN-GUERRERO
AEROVIAS LATINOAMERICANAS
AEROVIAS REFORMA, S. A.
AEROVIAS TRANSCONTINENTALES
AEROVIAS GUERRERO, S. A.
AVIONES DEL SUR, S. A.
BENJAMIN BON BUSTAMANTE
COMPANIA MEXICANA DE AVIACION, S. A.
COMPANIA TABASQUENA DE AVIACION
GUILLERMO FLORES PARKMAN
HELICOPTERO DE MEXICO
JORGE MASON
LINEAS AEREAS MEXICANAS, S. A.
LINEAS AEREAS GUERRERO-OAXACA, S. A.
LINEAS AEREAS PICHO
MAYO OBREGON
PRODUCTOS MARINOS DEL SURESTE
PRAXEDIS LOPEZ RAMOS
SERVICIOS AEREOS DE CHIAPAS
SERVICIOS AEREOS NACIONALES
TRANSPORTES AEREOS MEXICANOS
TRANSPORTES AEREOS JALISCO
TRANSPORTES AEREOS TAMPICO
TRANSPORTES AEREOS ROSALIA
TRANSPORTES AEROTERRESTRES
TOMAS ROBERTO CALDERON Y SOCIO
TRANSPORTES AEREOS

Air Freight Companies

COMPANIA DE PRODUCTOS DE CHICLE LOS "CHE-NES"
EMPRESA AEROCHICLERA, S. A.

Air Survey

COMPANIA MEXICANA AEROFOTO, S. A.

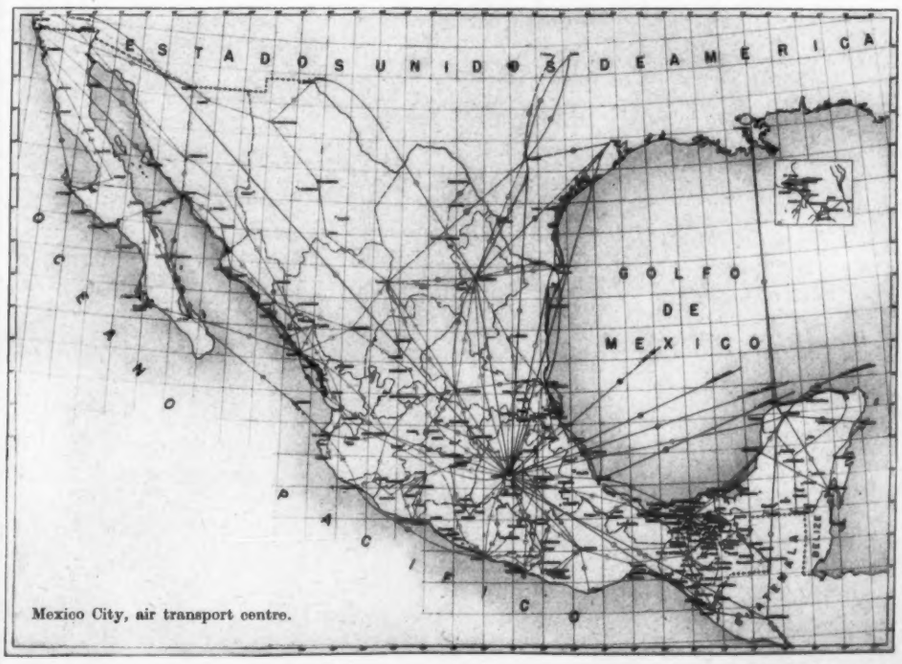
Agricultural Work

FUMIGACIONES AEREAS

Airlines with International Network

(Passengers, mail and freight)

AMERICAN AIRLINES, INC.
COMPANIA AEROTRANSPORTES, S. A.
AEROVIAS GUEST, S. A.
AEROVIAS "Q"
COMPANIA MEXICANA DE AVIACION, S. A.
LINEAS AEREAS MEXICANAS, S. A.
PAN AMERICAN AIRWAYS, INC.
TRANSPORTES AEREOS CENTROAMERICANOS
AIR FRANCE



Mexico City, air transport centre.

Family Resemblances in Jet Fighters

Was the MiG-15 modeled on the Ta 183?

BY HANS E. QUENZER, BREMEN

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History of the Ta 183

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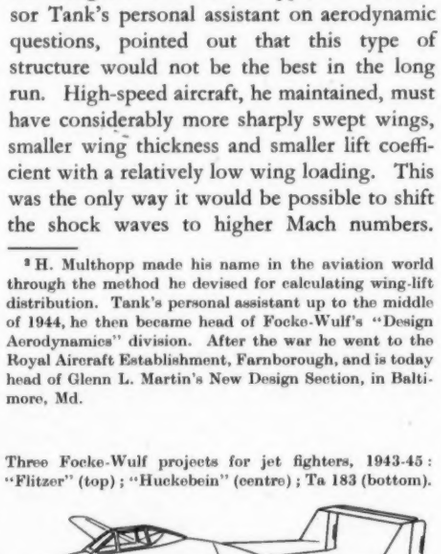
Three Focke-Wulf projects for jet fighters, 1943-45: "Flitzer" (top); "Huckebein" (centre); Ta 183 (bottom).



As a member of the German Academy of Aeronautical Research, Multhopp had the opportunity of examining important secret reports from German research centres on the problems of basic research, before they became available to the industry. He was therefore the first to be able to use these reports for a new jet fighter project, which featured a squat fuselage with central air intake, a wing leading edge swept back by 35 degrees and above all a long, oblique rudder unit. The latter was to have the sharply-swept elevator unit (leading edge sweep 45 degrees) fitted on top.

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However, as work continued on the project, considerable misgivings arose. Quite apart from flutter in the new-type tail unit, these concerned the balancing of the roll and yaw moment with the bucking moment to be expected from the oblique rudder unit axis, a balance which is of the utmost importance in air combat. A 1:10 scale glider model proved that the arrangement would fly in principle, but did nothing to solve the numerous problems involved.

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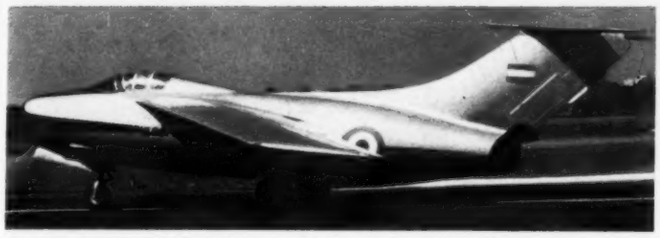

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Family likenesses

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Fact or fantasy ? Russian Mikoyan-Gurevich MiG-19 high-performance fighter, alleged to be a development of the MiG-15.

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Every aircraft—and particularly every fighter—is an organism whose parts must fit together from the points of view of space, weight and functioning. The change-over from a jet fighter with radial compressor engine to one with axial compressor, from a simple jet engine to one with an afterburner, or even to an undercarriage of different design or size, results in far-reaching structural modifications, which generally also affect external shape. The method of fitting the undercarriage, or a change in engine attachments or fuel tanks entail changes in the position of the wings, in the centre of gravity, in the shape of the tail, each modification leading on to another.

On the other hand the configuration of jet fighters throughout the world is progressing towards an optimum form corresponding to the present-day position in basic research. Knowledge of the qualities of swept wings at high speeds and of the optimum design of air intakes had probably been acquired earlier in Germany than elsewhere. This knowledge went into the Ta 183, the fruits of which may have been reaped by other designers. But whether the Ta 183, designed for an engine of 2860 lbs. thrust (with provision for 3960 lbs. later), without facilities for the installation of an afterburner, with fuel tanks too small for today's conditions, could really have met the need of our days is more than doubtful. However, it has been clearly demonstrated that the basic principles of this design have proved correct and have since become common property.

Aircraft type		Tank Ta 183	Instituto Aerotecnico I.Ae. 33 "Pulqui 2"	Mikoyan MiG-15	Svenska Aeroplan J 29
Engine type		Heinkel-Hirth HeS 011	Rolls-Royce "Nene 2"	Chelomey (Nene)	De Havilland (SFA) "Ghost"
Static thrust	lbs.	2870	5000	4850	5000
Span	ft.	approx. 36'	34' 9"	33' 2"	36' 1"
Length	ft.	approx. 36'	38'	36' 3"	33' 2½"
Height	ft.	—	10' 10"	11' 2"	12' 3½"
Wing area	sq.ft.	260	270	256	258
Sweep					
Wing leading edge	degrees	35°	approx. 40°	35°	25°
Tailplane leading edge	degrees	40°	45°	—	approx. 35°
Rudder unit leading edge	degrees	approx. 40°	50°	—	approx. 45°
Weight empty	lbs.	6600	7940	7940	—
Gross weight	lbs.	approx. 11,000	12,235	13,600	—
Maximal speed	m.p.h.	635	646	685	660
Rate of climb	ft./min.	—	5870	8200	—
Service ceiling	ft.	—	50,000	50,000	—
Endurance	hrs.	3	—	1	—

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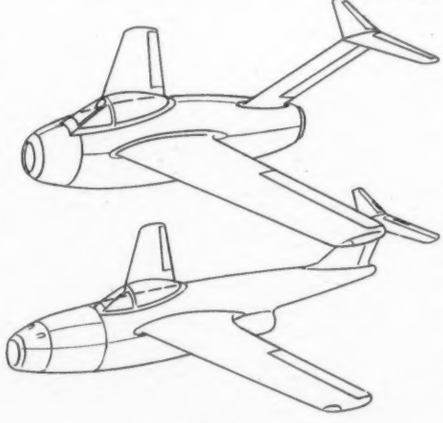

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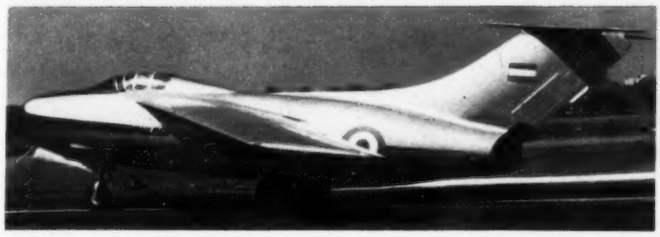

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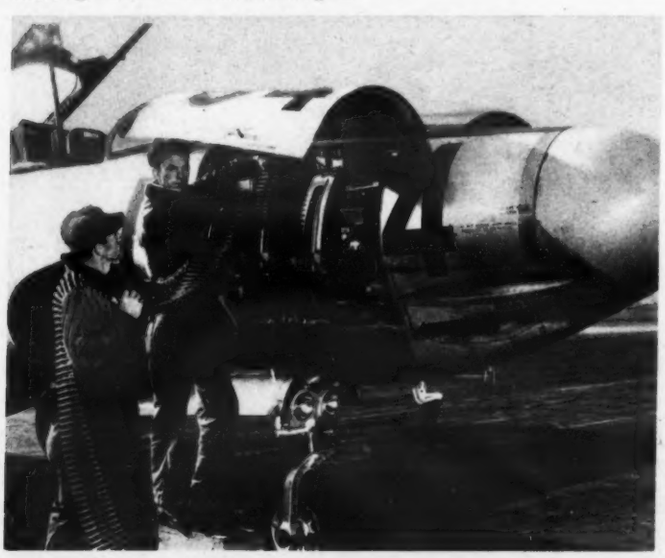
Guardians of New York

The Lockheed F-94A's of the 4709th Defense Wing at McGuire Air Force Base, Trenton, N.J., are kept in a permanent state of readiness. Here the crew's oxygen supply is replenished. The nose bulge houses the radar equipment. Underneath are the four .50 machine-guns.

The Solar afterburner in the F-94A's tail, which boosts the power of the Allison J-35-A-33 jet from 3,900 lbs. to 5,200 lbs.s.t.

Reloading the four .50-in. cal. machine-guns.

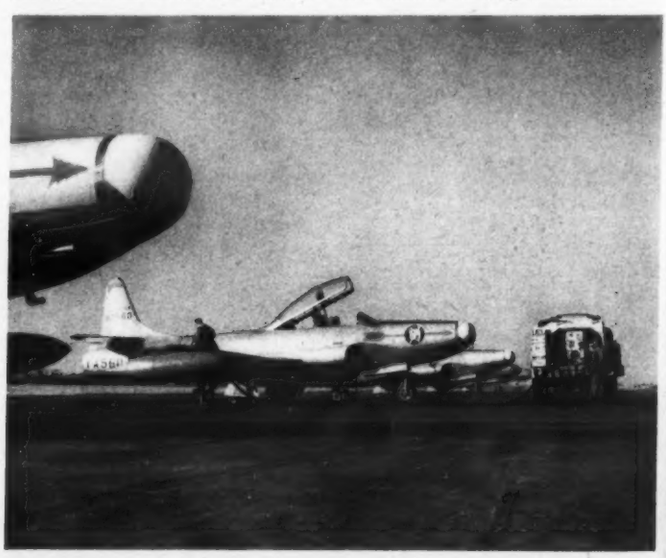


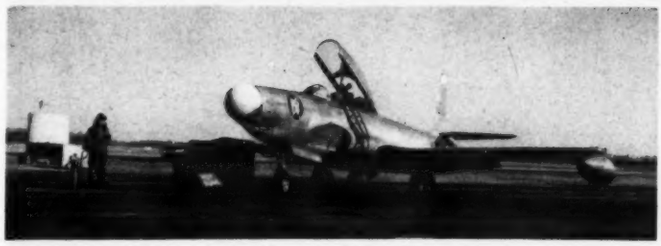
Twenty-four hour protection is now provided for New York and the Industrial East of the United States by a chain of day-and-night fighter squadrons of the U.S. Air Force which are maintained on a permanent stand-by alert. One of the units guarding America's metropolis is the 4709th Defense Wing stationed at McGuire Air Force Base, Trenton, New Jersey—a few jet minutes from New York City. The Wing has two squadrons of fast-climbing, radar-equipped Lockheed F-94 "Starfire" jets.

Day and night, winter and summer, rain or shine, the "alert trailer" waits on the fighter line with its complement of pilots, radar operators and ground crews, whiling away their time playing cards, talking about the girls or indulging in the old-fashioned but ever popular "hangar flying." But at the first sign of an unidentified aircraft being picked up on the scopes of the ground radar warning units, the order "scramble" is flashed to the alert crews. Flight and ground personnel rush to their aircraft, which are always fully armed and fuelled, with engine energizers permanently plugged in. Pilot and radar observer hop into their F-94, the ground crew chief helps "button up" the pilot in his cockpit, the observer straps himself in and readies his radar scope. The Allison jet is fired, the energizer removed, the chocks pulled, and the F-94 roars down the runway to seek out and identify the "bogey." Radar-guided by ground-control interception, the fighter reaches the vicinity of the unidentified aircraft, its airborne radar takes over and brings it into visual range. When recognition is made and the other aircraft is "friendly," the "bogey" is allowed to continue on its way. Otherwise . . .

The 4709th Defense Wing was originally activated at Selfridge AFB, Michigan, in January, 1941, as the 52nd Pursuit Group. Its wartime service began with sweeps over Northern France with Supermarine "Spitfire" fighters. It took part in the invasion of North Africa in November, 1942, flying its "Spits" off a carrier to provide ground support at Oran. From Oran it moved across North Africa to Sicily, to Corsica, up the Italian mainland. It then changed its operational

Fuelling the F-94A's to keep them in permanent readiness on the flight line. The last two machines on the line are Lockheed T-33 transition and navigation trainers.





An armed guard stands by one of the "alert" F-94A's. The machine is fully armed, the energizer is plugged in to make possible a quick getaway. Trailer in left background houses alert crews.

"Scramble . . ." Crews and ground personnel race to their aircraft.

mission from giving close support to that of providing long-range fighter escort to the heart of Berlin with North American F-51 "Mustangs." During its combat operations the group achieved a total of 421 air victories.

The 52nd Pursuit Group was inactivated in November 1945 but reformed—redesignated the 52nd Fighter Goup—in November 1946 as an all-weather unit destined for Europe. In June 1947 it was again renamed, this time as the 52nd Fighter Wing ; it was transferred to USAF's Air Defense Command, shifted to Mitchell AFB, Hempstead, N.Y., and equipped with North American F-82F "Twin Mustang" night fighters. It moved to McGuire in October 1949 and re-equipped with F-94 "Starfire" jets in mid-1950. Earlier this year it changed its name to 4709th Defense Wing.

Another important link in the all-weather fighter chain along the U.S. East Coast is the unit until recently designated the 33rd Fighter-Interceptor Wing, which is based on Otis AFB, out on Cape Cod, Mass. Also under USAF Air Defense Command, it flies the same type of aircraft as the 4709th in its mission of helping to defend the Continental United States against air attack.

Pilot and radar observer climb into their F-94A fighter, with crew chief standing by.

The Lockheed F-94A "Starfire"

Span	38 ft. 10½ in.
Length	40 ft. 1½ in.
Height	12 ft. 8 in.
Wing area	237.6 sq.ft.
Wing loading	64.5 lbs./sq.ft.
Power loading	3.9 lbs./lb.s.t.
Gross weight	15,330 lbs.
Empty weight	9,557 lbs.
Power plant : Allison J-33-A-33 of	3,900 lbs.s.t.
with Solar afterburner, boosting power to	5,200 lbs.s.t.
Top speed at sea level	600 m.p.h.-plus
Service ceiling	45,000 ft.
Armament	four .50-in. cal. machine-guns.

A later version, the F-94B, is now going into service. It has improved radar and other equipment, as well as large-capacity, non-jettisonable wing-tip tanks.

Crew chief "buttons up" the pilot, while a second crew man stands by the energizer. Radar operator in rear seat is adjusting radar scope.

Lockheed F-94B's are now going into service. This is an improved version, sporting large, non-jettisonable wing tanks.

The Lockheed F-94A "Starfire" all-weather fighter taxies out for take-off.

The IATA Conference in Copenhagen

The Lord Mayor of Copenhagen, H. P. Sörensen, opening the proceedings of the fifth IATA Technical Conference at Copenhagen, which was attended by over 200 experts from all over the world. Left to right: Knud Lybye, SAS, E. Möller-Hansen, Danish CAA, Hipson-Leeman, USAF MATS, J. M. Beardslee, U.S. CAA, Per Kampmann, Chairman of the Board, SAS. Knud Ree, Danish Ministry of Public Works, J. C. Kelly-Rogers, Aer Lingus, H. P. Sörensen, Lord Mayor of Copenhagen, Sir William Hildred, IATA, Palle Christensen, Danish Ministry of Public Works, A. Ferrier, ICAO, A. H. Nagle, World Meteorological Organization, Per M. Backe, SAS, Knut Hagerup-Svendsen, SAS, and Stanislaw Krzyczkowski, IATA.

From May 5th to 17th the Danish capital was the scene of the International Air Transport Association's *Fifth Annual Technical Conference*. This conference was attended not only by representatives of IATA's 62 member countries but also by industrialists and land and sea transport experts from all over the world. Some of the Western powers had sent members of their air forces, notably the RAF and the U.S. Military Air Transport Command. Then there were leading personalities from the International Civil Aviation Organization, the World Meteorological Organization, the U.S. Civil Aeronautics Administration, the British Air Registration Board and the Royal Aircraft Establishment, Farnborough. And such leading firms as Bendix Aviation Corporation, Consolidated Vultee, Goodyear, International Aeradio, Philips Radio (Holland), Radio Corporation of America and the Sperry Corporation had also sent observers.

Two main subjects were discussed during the two weeks' conference, namely the present position and future development of airborne radio equipment, and landing approach and landing. The primary aim was to get a detailed exchange of views between representatives of airlines, ground organizations, etc. and the makers of aircraft radio equipment. Hence no final decisions were made, the conference merely working out the general lines along which equipment should be developed to meet the expected future increase in air transport. A number of recommendations will probably be taken up at the meeting of the ICAO's Committee on Airports, Airways and Ground Navigation Aids in Montreal (October 21st, 1952).

The following are some of the most interesting of the many points discussed—the report on the conference covers over 1000 pages: It was found that R/T communications between aircraft and ground stations were more and more being made by VHF, but that HF was still in use in many places and would probably continue in use for several years to come.—Special attention should be given to the training of aircraft crews and air traffic control personnel in clear *pronunciation*, which, in the view of delegates, is just as important to the general improvement of R/T communications as purely technical advances. The vocabulary to be used for R/T communications should also be chosen more carefully and defined more exactly. Delegates found that improvement was urgently needed in the transmission and presentation of radio messages on board aircraft, and that the possibilities of television should be investigated.

On the subject of "landing approach and landing" it was recommended that ICAO's minimum requirement for vertical visibility for instrument landings (at present 80 to 100 m.) should be reduced. However this would have to be preceded by an improvement in existing navigation aids and the observance of stricter approach rules. Not only electronic aids to bad weather approach need improving but also optical aids (airports lighting, etc.) must be developed further and adapted to the radio aids. By using combined systems it should be possible to operate with a minimum vertical visibility of 30 to 50 m. (break-off height), at any rate for present-day propeller-driven aircraft.

It was agreed that airways and air traffic control had by no means reached the limits of its possibilities. Truly all-weather air transport would still require very much improvement of both a technical and an organizational character.

What?—Where?—When?

IATA	Accounting and Statistical Sub-Committee	—	Summer*
IATA	Facilitation Sub-Committee	—	Summer
—	All Women's Transcontinental Air Race (Santa Ana, Calif., to Teterboro, N.J.)		July 4-9
NACA	National Advisory Committee on Aeronautics - Biennial Inspection of Ames Aeronautical Laboratory	Moffett Field California	July 14-15
IAS	Institute of the Aeronautical Sciences, Annual Summer Meeting	Los Angeles California	July 16-18
ICAO	Aeronautical Information Services Division, 1st Session	Montreal	August 19
—	International Conference on Materials and Structures	Trondheim	August
WMO	World Meteorological Organization - Third Session of WMO Executive Committee	Geneva	September
—	International Technical Committee for Fire Prevention	Switzerland	September
SBAC	Society of British Aircraft Constructors, Air Display and Exhibition	Farnborough	September 2-7
ASME	American Society of Mechanical Engineers, International Conference	Cleveland Ohio	September 8
ICAO	International Conference on the Revision of the 1933 Rome Convention	—	September 9
IATA	Executive Committee - 24th Meeting	Geneva	September 12
—	2nd European Machine Tools Exhibition	Hanover	Sept. 14-23
IATA	8th Annual General Meeting	Geneva	September 15
IATA	Traffic Conference 1 Agency Sub-Committee - 15th Meeting	—	September 16
ICAO	Statistics Division (STA), 2nd Session	Montreal	September 16
—	Royal Swedish Society of Engineering Sciences Meeting	Stockholm	September 22
SAE	Society of Automotive Engineers - National Aeronautical Meeting, Aircraft Engineering Display and Production Forum	Los Angeles	October 1-4
IATA	Traffic Conference 2 Agency Sub-Committee - 16th Meeting	Paris	October 7
IATA	Traffic Conference 3 Agency Sub-Committee - 13th Meeting	Singapore*	Autumn*
ICAO	Aerodromes, Air Routes and Ground Aids Division, 5th Session	Montreal	October 21
SAE	Society of Automotive Engineers - National Fuels and Lubricants Meeting	Tulsa Oklahoma	November 6-7
IAS	Institute of the Aeronautical Sciences, 16th Wright Brothers Lecture	Washington	December 17

* Tentative.

What's in the Air ? *

AIR TRANSPORTATION

World air transport

● According to statistics prepared by KLM Royal Dutch Airlines, 39,000,000 passengers were carried by the world's scheduled airlines in 1951, a daily average of 107,000 passengers. The number of aircraft operated by the scheduled companies is estimated at 2,250, and personnel at 200,000.

● *Oil strike.*—The strike by 90,000 workers in the American petrolum industry—in almost all States—lasting from the beginning to the middle of May, has led to fuel rationing and thus to certain reductions in commercial air services. Airlines usually work with a fuel reserve for two to three weeks, and the authorities of the various countries involved seem to be insisting that full operation should not be resumed until stocks are at least back to normal level, or possibly still higher, in view of the present uncertain world conditions. On an average normal supplies have been reduced by one third, with cuts of 35 % in Great Britain, France, Western Germany (by order of the Allied High Commissioners), South Africa, Australia ; 40 % in Switzerland (prohibition of all pleasure flights, such as Alpine flights etc.); 30 % in SAS.—However most airlines have managed to keep up the majority of their services on long-distance international routes.

● *North Atlantic.*—On May 20th and 21st, 1952, the 25th anniversary of Lindbergh's flight, IATA reports, roughly 1800 passengers crossed the Atlantic in 33 hours 30 mins., the time taken by Lindbergh for his crossing.

USA

● *Ground organization.*—The *Airport Commission* set up by President Truman to investigate the airport problem in the light of the three serious accidents at Elizabeth, Newark, has now submitted its final report. The 126-page booklet, entitled "*The Airport and its Neighbors*," makes 25 major and dozens of lesser recommendations for safeguarding life, reducing noise and making improvements at airports in congested areas. —The following is a brief summary of the major points :

1) Single or parallel runways in least congested direction, instead of intersecting runways; modern aircraft can land in moderately high cross winds, thanks to their special undercarriage.
2) No buildings to be permitted within 2½ miles (4 km) of the ends of the runways.
3) Increased minimum cloud ceilings under which aircraft must manoeuvre over congested areas.
4) Speed-up in the installation of radar traffic control and other landing and take-off aids.
5) Tighter Government control of airport design and operation.
6) Increase in Government aid for the modernization of airports.
7) Strict separation of military and civil operations wherever possible (ban on experimental and training flights in the area of a commercial airport).

● "*Snail mail.*"—American business circles are complaining of delays in mail deliveries. The name "snail mail" has already been coined, and many people are objecting that it is useless to send mail by air if it is going to wait at its destination until the train mail arrives.—Postmaster General Jesse M. Donaldson puts the blame on the sharp cuts made by Congress in mail appropriations in recent years. There are now only three deliveries a day in business districts and one a day in residential areas. It would cost at least $150 millions to restore service to its old standard.

During a *visit of French aviation personalities to the American West Coast,* Louis Bréguet (left) and Pierre Bréguet (right) were invited to the Lockheed plant at Burbank, California, where they were received by Lockheed President Robert E. Gross (centre).

● *PAA versus TWA.*—The Civil Aeronautics Board closed its hearings in mid-May on the PAA-TWA Atlantic dispute, and its decision will shortly be made public. TWA had urged that PAA's services to Paris and Rome be cancelled and asked that its own Far East services be extended. PAA is fighting for the status quo. —The case has been complicated by the appearance of a new competitor in American overseas traffic—the European-American Airlines Inc., a freight company recently founded in Washington, which has applied to the CAB for permission to fly to the major European centres, such as Shannon, London, Paris, Amsterdam, Brussels, etc.

France—Mexico

● Air France opened its new Paris—New York—Mexico City service on April 27th. The service is to be operated twice a week by Lockheed "Constellations."

Great Britain

● BOAC's Chairman, Sir Miles Thomas, stated in mid-May that even apart from the shortage in aviation spirit there are signs of a falling off in international air traffic. He added : "As I travel around the world I am beginning, in the last two or three months, to sense that there is a suggestion of recession in the air. The sellers' honeymoon is going to end. It is not going to be long before there are some pretty tough propositions facing everybody in the commercial field." ... It remains to be seen whether this somewhat pessimistic forecast will be confirmed by events, or whether it is merely a precautionary antidote to BOAC's recent rather rosy business report. For the financial year which ended on March 31st, 1952, BOAC reported a profit of £268,000, compared with losses of £4,565,000 for 1950/51 and £7,792,000 in 1949/50.

USSR

● More substantial details than usual are available of the activity of *Aeroflot,* Russia's national airline. International services are restricted to the capitals of the satellite states, with the addition of a weekly service to Tirana (Albania), with a *technical landing* at Belgrade (!) (i.e. without picking up either passengers or freight). There are notable *increases in the frequency of services to Asia :* daily from Moscow to Vladivostok (the Russian Pacific port).—New services : Moscow—Ashkabad (capital of the Central Asian Republic of Turkmenia, flying time 13 hrs. 25 mins.) ; Tbilisi (capital of Georgia)—Baku (oil centre)—Ashkabad—Tashkent (atomic centre in Central Asia), etc. — Aeroflot has no night services (except in the region of the "midnight sun"). The major booking office is in Moscow's Hotel Metropole. Foreigners buying tickets must produce a permit from the Air Ministry.—The conditions of carriage contain the following provisions : no refreshments are served on board the aircraft ; schedules may be changed without notice and should be checked up to the last moment ; should a passenger be prevented by the authorities from making a flight his fare will not be reimbursed.

Test pilot Squadron Leader Jan Zurakowski (famous for the new "double cartwheel" aerobatic figure he demonstrated at Farnborough in 1951) has left Gloster Aircraft Co. for Avro Canada.

Hiller 360 helicopter of the 1st Airborne Command, French Colonial Forces, on ambulance duties in the Hatier region (Vietnam).

* Extracts from "Interavia Air Letter," daily international news digest, in English and French. All rights reserved.

INDUSTRY

USA

● *Lower profits in 1951.*—A New York National City Bank economic survey shows that the profits of the American aircraft industry and accessory firms in 1951 fell off considerably. After deduction of taxes, raw materials, wages and other expenses firms were left with an average of 2.2 cents per dollar sales for renewal of equipment, expansion of plant, research work and

"Spring cleaning" at an advanced airfield in Kienan.

the payment of dividends. This is only half of last year's figure. Other American industries had worked with profits of 6.2 cents per dollar sales. The National City Bank calculated a total net profit of $57,560,000 for 29 aircraft firms in the aircraft industry (a reduction of 32% compared with the results for 1950).

● *CAB asks jet transport subsidies.*—Donald W. Nyrop, Chairman of the U.S. Civil Aeronautics Board, speaking recently before the Senate Interstate and Foreign Commerce Committee, made a particularly urgent plea for subsidies to assist the development of jet airliners. He referred to all previous schemes as inadequate and warned against allowing America to be overtaken by other countries. Nyrop advocated the following plan: A Government loan for every promising project, up to 75% of the development costs (estimated at $20,000,000), the loan to run for ten years at 1% interest. The producer should have his debt reduced by $1,000,000 for each of the first fifteen aircraft sold, so that once these fifteen were sold the loan would be wiped out.—In addition CAB should be empowered to pay every airline employing American jet aircraft the sum of $1,000,000 per aircraft for the first operating year.—*Senator Pat McCarren*—one of air transportation's most enthusiastic supporters—suggested that the Governments hould reimburse airlines the difference in the cost of American jet aircraft, since the British could undersell the Americans for several years to come.—The project was opposed by the newly-appointed Under-Secretary for Transportation at the Commerce Department, Jack Garrett Scott, who felt that private capital was quite capable of financing development.—The U.S. Department of Defense, in a letter to the Senate Interstate and Foreign Commerce Committee, stated that it was against the development of civil jet aircraft at the present moment because this might interfere with military aircraft production.

● Unlike many other aircraft plants, who have been cutting down their work week, Republic Aviation Corp. has gone on to a ten-hour day to speed up production of spares for the F-84E and F-84F "Thunderjets."

Italy

● *Fiat's profit.*—Professor Vittorio Valetta, Fiat's Chairman, reported to the firm's general meeting on April 10th a profit for 1951 of 4,298,000,000 lire (dividend 50 lire per share). The turnover of 170,000,000,000 lire was 20,000,000,000 lire higher than in the previous year (in spite of a falling off on the domestic market since the summer of 1951). The firm at present employs 65,000 persons.

FLYING EQUIPMENT

U.S. Air Force "Thunderjets"

● The Republic F-84 "Thunderjet" single-engined jet fighter, with the Lockheed "Shooting Star" and the North American "Sabre," forms the standard flying equipment of the U.S. Air Force fighter units. It has successfully withstood its trial of fire in Korea.

However it is agreed that further development of the F-84 would only be justified if the already high performance of this type could be still further improved. The *F-84F* fighter-bomber version recently announced appears to fulfil this condition. No exact performance data are at present obtainable, but it has been stated that the new type is superior "in every way" to the earlier F-84E. In other words, the F-84F's top speed probably exceeds 620 m.p.h., its ceiling 45,000 ft. and range 1000 miles. Such performance is quite likely when it is considered that the F-84F has a Wright J-65 "Sapphire" of over 7,200 lbs. thrust, compared with the 5000-lb. thrust of the Allison J-35-A-17 in the F-84E. The F series also has a swept wing and swept tail unit, unlike the straight surfaces in the F-84E. Finally the

The prototypes of the Republic F-84F fighter bomber (foreground) and the RF-84F "Thunderjet" photo reconnaissance model in formation over the Californian desert. Both aircraft are fitted with Wright J-65 "Sapphire" jet engine of over 7200 lbs. thrust.

nose air intake has been replaced in the F-84F by wing root intakes.

Republic have also brought out a *photo reconnaissance version RF-84F.* Both types are to go into quantity production before the end of the year.

A Japanese helicopter

Reports from Tokyo show that Japan's aircraft industry is coming to life again. Some time ago Douglas Aircraft Co. sent a group of experts to Japan, and now Bell Aircraft Corp. seem to be taking an interest in the potentialities of the Japanese market. Nippon

The recently opened school for control tower officials at Munich is training 86 pupils (mostly from the former Luftwaffe).

A Chance Vought F7U "Cutlass" twin-engined jet fighter shortly after take-off from the deck of an aircraft carrier. The "Cutlass" is being built in large quantities for the U.S. Navy.

Kikai Boeki K. Kaiska (Japanese Machine Trading Co.) is said to have received licence rights for the production of Bell helicopters. The names of former well-known aircraft firms, such as Fuji Kogyo (formerly Nakajima) and Kawasaki Kikai, have also been mentioned in this connection.

A Japanese Helicopter Research Association has been set up by the Yomiuri press. Its first design, the *Yomiuri Y-1*, has already come out.

The Yomiuri Y-1 is a two-seater of traditional design (seats side-by-side) with a two-bladed main rotor and three-bladed tail rotor. Main rotor has stabilizing bar similar to the Bell system. Fitted with a 150 h.p. engine of undisclosed make, the helicopter (gross weight 1650 lbs.) has a max. level speed of 87 m.p.h., a rate of climb of 395 ft./min. and a range of about 155 miles. Rotor diameter 29 ft. 6 in., length 34 ft. 8 in., height 8 ft. 2 in.

SERVICE AVIATION

NATO forces

● Under a reorganization of the tactical air forces of the Allied Air Forces in Central Europe (commander Lieutenant General Lauris Norstad), *two new air commands have been formed:* (1) the *Second Allied Tactical Air Force,* under the command of Air Marshal Sir Robert Foster, RAF, in Northern Germany, including the RAF Second Tactical Air Force in Germany, the Headquarters of the Netherlands Tactical Air Command and two squadrons of the Netherlands Air Force, and the Belgian Second Air Wing comprising three squadrons. (2) The *Fourth Allied Tactical Air Force,* under Major General Dean Strother, USAF, in Southern Germany, including the U.S. Twelfth Air Force, the First French Air Division (three wings), and (later in 1952) a Royal Canadian Air Force fighter division (several squadrons), now based in Britain awaiting the provision of suitable airfields on the Continent.

Great Britain

● *"Big Six" programme.*—Military sources in London claim that certain delays in the supply of the aircraft included in the "Big Six" super-priority programme are inevitable. The programme, for which the industry was given priorities in personnel, raw materials, machinery, production plant, comprises six groups of war material:

1) The six newest jet aircraft types: Hawker P.1067 "Hunter" and Vickers Supermarine "Swift" jet fighters; English Electric "Canberra" and the four-engined Vickers Armstrongs 660 "Valiant" (atomic-bomb carrier); the Fairey "Gannet" anti-submarine aircraft (propeller turbine); and an undisclosed all-weather jet fighter (probably the Gloster GA-5 or de Havilland DH 110);
2) Guided missiles;
3) Aircraft ammunition;
4) Radar equipment;
5) Anti-mine equipment;
6) "Centurion" tanks.

Combustion Chambers for Turbine Power Plants

by Dr. Ing. HERBERT WEHNER, Stuttgart

During the past fifteen years there have been tremendous developments in turbine engines, both turbo-jets and shaft turbine engines. Turbo-jets are used exclusively in aviation, whilst shaft turbine engines have wider uses, with only the propeller turbines being employed in aircraft. Alongside these there are a number of stationary shaft engines running with good results. Finally gas turbines are suitable for land vehicles and surface craft, as has been shown by British and American experiments on a turbo-automobile and several fast naval craft.

What uses turbine engines will finally be put to depends on detail development, which is now in full swing. The design of compressors and decompression turbines sets a number of problems, of a design, metallurgical or production character, which can only be solved step by step and at considerable cost. An equally difficult problem is that of the development of combustion chambers, the present position of which is outlined below.

Types of combustion chambers

Combustion chambers are the parts of a turbine engine between the compressor and the turbine. It is here that heat is applied, as a rule through the combustion of liquid fuels. To make flow conditions as simple as possible (straight flow), the combustion chambers in aircraft engines are generally situated literally between compressor and turbine. In this case two types of structure are distinguishable :—

annular combusion chambers (fig. 1)
single or can-type combustion chambers (fig. 2)

Both types have their advantages and their disadvantages. The annular combustion chamber is undoubtedly superior in its utilization of space. However, when it needs replacing the whole engine has to be dismantled. This disadvantage does not exist in the can-type combustion chamber. On the other hand difficulties are often experienced in the latter in connection with the regular distribution and mixing of the hot air-gas flow. [1]

It should be mentioned here that the temperature distribution of the gases at the turbine inlet must be as regular as possible. The magnitude of the temperature is limited by the thermal load capacity of the turbine blades, and is today between 800 and 900°C. This temperature and the total air mass flow also determines the amount of fuel to be injected. In general about four times as much air must be added as would be necessary for full combustion of the fuel. To get optimum combustion conditions only part of the air flow (primary or combustion air) is added to the fuel in the combustion chamber. The remainder, the so-called secondary or mixing air, flows past the combustion zone and is added to the hot gases when combustion of the fuel in the primary air has been completed.

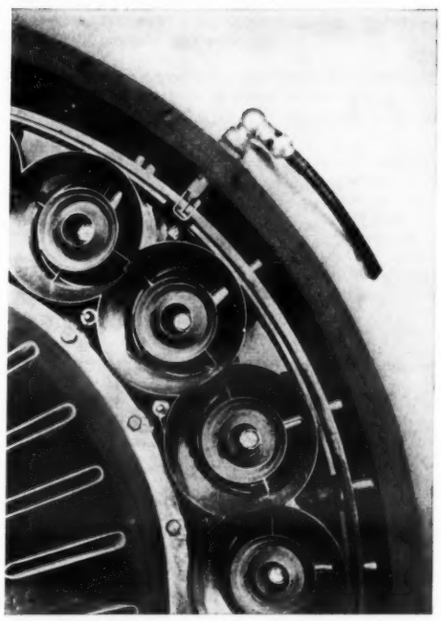
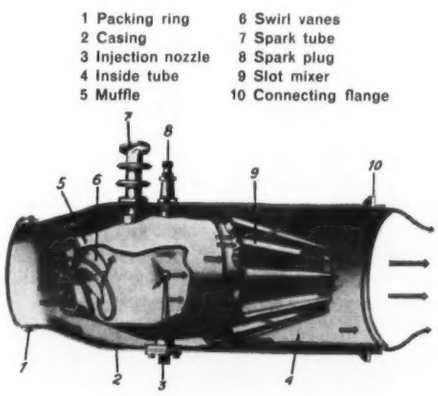


Fig. 1 : Open annular combustion chamber (ATAR 101) with outer casing (which also carries secondary air mixing vanes) removed. Section shows, working towards the centre, starting plug; combustion ring (primary air enters through 20 conical burners); inner secondary air mixing vanes.

Fig. 2 : Structure of a can-type combustion chamber (Jumo 004).



The weight ratio of the total air flow through the combustion chamber (or turbine) to the air required in the stoichiometric mixture (one which has neither surplus oxygen nor surplus fuel) is designated *air ratio* λ, and that of the secondary air to the primary air as *secondary air mixture ratio* μ.

To complete the picture it must be stated that there are also combustion chambers without turbines after them. They are used with *afterburners* (devices for extra heating to give short-period thrust boosts) and with *ramjets* (for high-speed aircraft and guided missiles). In essentials, they consist of a tubular combustion chamber, grid-like flame holders and a fuel injection device. There is no need here to pay attention to temperature distribution or restriction. Thus, in order to get highest possible temperatures, a stoichiometric mixture of fuel and combustion air ($\lambda = 1$) is aimed at. In practice the best rates of efficiency, however, are always obtained with an air surplus, which is needed to prevent localized incomplete combustion due to unstable fuel distribution. The final temperature today obtained in combustion chambers of this kind is between 1500 and 1600°C.

Requirements and solutions

Requirements of a combustion chamber can be summarized as follows :—

1. Maximum possible conversion of chemical energy into heat.
2. Minimum loss in pressure in the air flow.
3. High specific thermal stress (per unit volume).
4. High specific air mass flow (per unit area).
5. Stable combustion within the largest possible temperature, pressure and speed ranges.

[1] Editor's note : This seems to be misleading : even distribution and combustion in the *annular* is one of its chief drawbacks. The *aim* of annular design is to get simplicity and lightness, but owing to fuel mixing difficulties this type of combustion chamber is usually heavier than separate cans.

6. Ease of regulation.
7. Stable distribution of temperature at combustion chamber outlet.
8. Thermal resistance to high temperatures and rapid changes in temperature.
9. Avoidance of solid deposits.
10. Light-weight structure and simple design.

A number of coefficients have been introduced so that these requirements can be indicated in figures:

1. The rate of energy conversion, i.e., the quality of combustion, is measured by the *combustion efficiency*. It is defined as the ratio of the temperature increase actually obtained in the combustion chamber to the temperature rise theoretically obtainable with complete combustion of the fuel.

$$\eta_v = \frac{\Delta t_w}{\Delta t_{th}} 100 \quad (\%)$$

The combustion efficiency is the combustion chamber's most important coefficient. The possibilities of improving it will be dealt with later.

2. *Pressure drop* is often given as a percentage, though it can also be given with reference to the specific weight of the air at the combustion chamber inlet and thus take on the dimensions of a loss in pressure height (metres). Even air flowing through a combustion chamber without combustion suffers a loss in pressure, which, other things being equal, increases with the square of the air mass flow. With a given air mass flow an increasing temperature rise in the combustion chamber leads to a further rectilinear increase in pressure drop (fig. 3) [2].

3. The *combustion chamber stress* (thermal stress per unit volume) is today between 100×10^6 and 250×10^6 kcal/m³h. In experimental runs 300×10^6 kcal/m³h has even been reached and exceeded. On the other hand combustion chamber stresses in modern boiler fired engines are a hundred times lower.

4. The so-called *mean passage time*, defined as the ratio of the combustion chamber volume to the volume flow per second, is no more than 3 to 6 thousandths of a second in modern combustion chambers.

*

Although the various values which influence combustion are today widely known, the main weight in the development of combustion chambers is still placed on test bench experiments. It depends in part on the test engineer's experience how long it takes—and with what success—to find a combustion chamber which meets requirements. Since experiments are not as a rule carried out under true operating conditions, the choice of suitable test conditions is of decisive importance.

[2] The pressure drop can be divided into a *flow loss* and a *thermodynamic loss*. The latter is of virtually no importance in normal combustion chambers, but plays a big part in afterburners. It can be calculated by the method indicated by R. Focke (" Thermodynamik in strömenden Gasen ", ZWB Vol. 9, 1942, No. 5).

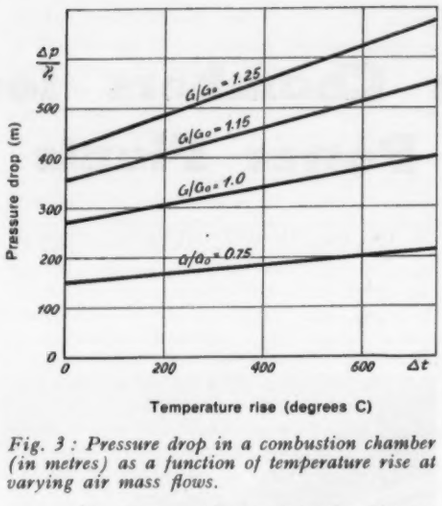


Fig. 3 : Pressure drop in a combustion chamber (in metres) as a function of temperature rise at varying air mass flows.

Δp = pressure difference between combustion chamber inlet and outlet
γ_1 = specific weight of air at combustion chamber inlet
G = real air mass flow
G_0 = air mass flow at full load

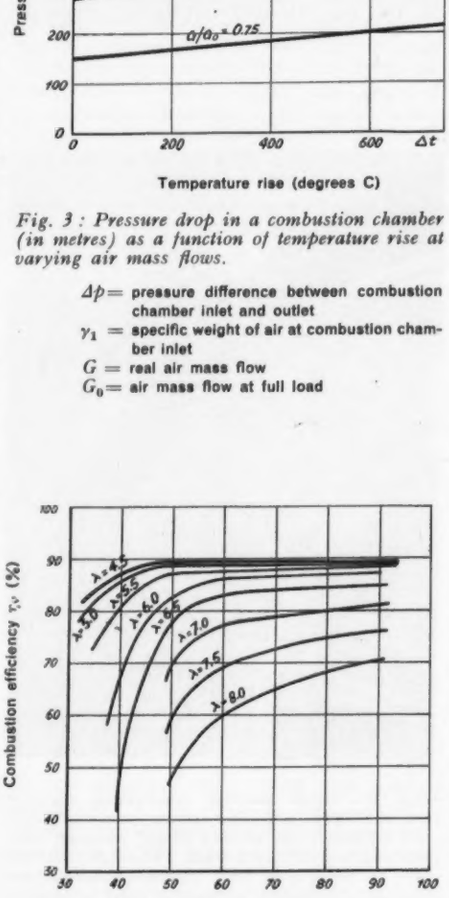


Fig. 4 : Influence of air temperature (primary air at inlet to combustion chamber) on combustion efficiency with various air ratios in a combustion chamber with little turbulence.

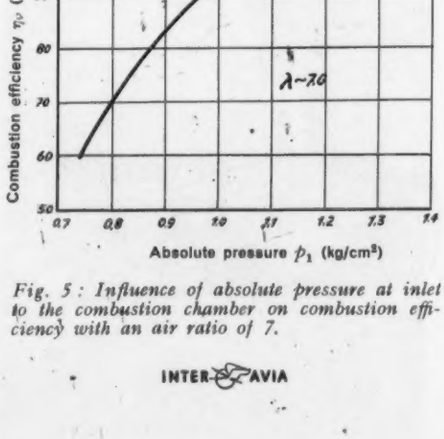


Fig. 5 : Influence of absolute pressure at inlet to the combustion chamber on combustion efficiency with an air ratio of 7.

The usual method is as follows: the combustion chamber is examined with the gases flowing out freely into the atmosphere, the speed of flow chosen being that of practical operation. The density of the air will as a rule be lower than in practice. The practice of heating up the air in front of the combustion chamber inlet is dispensed with, but then the temperature of the air is also lower. In aircraft engines this corresponds to the running conditions experienced in high altitude flight.

The further development of the combustion chamber, in particular as regards thermal resistance and deposits, is done in the actual engine. Both factors are affected by pressure, the wall temperatures, thanks to better heat transfer coefficients, rising with increasing pressure, and both weight of air flowing through and thermal stress also increasing.

However, a combustion chamber can also be developed on the test bench under true operating conditions. This, of course, is more costly, measurements and observations are more difficult to make, and modifications take longer [3]. Empirical methods will, however, continue to be indispensable until mathematical treatment of the various overlapping factors is possible [4]. There are no laws of similarity for combustion chambers as a whole.

Values influencing combustion efficiency

Entry temperature : As may be seen from fig. 4, the air temperature at the entry to the combustion chamber has a very great influence on combustion efficiency. The combustion chamber used for the measurements had only slight turbulence, so that variations in combustion efficiency were more noticeable than usual. The influence of the air ratio is also seen. The important feature here is *not* the absolute values, which also depend on other factors, but the tendencies of the curves. This applies above all in the range of low temperatures which are important during starting. The increase in combustion efficiency with increasing temperature is explained by the fuel's greater tendency to vaporise and by the growing reaction speeds. The lapse of time between arrival at the mixture's temperature of spontaneous ignition and the beginning of the exothermal reaction is greatly reduced.

Pressure : Since reaction speed increases with concentration, combustion efficiency increases with increasing pressure in the combustion chamber *(fig. 5)*. This is the explanation of the frequent failure of early jet engines, in which any sudden change in running conditions at altitude was followed by either the complete extinction of the combustion chamber or the reduction of combustion efficiency to such a low level that the

[3] Another method consists of testing the combustion chamber at one of its stability limits. Cf. "*Combustion Studies Offer New Efficiencies*" in Aviation Week, April 4th, 1949.

[4] Problems of combustion chamber design and fuels were discussed by *I. Lubbock*, in a paper read to the North East Coast Institution of Engineers and Shipbuilders, at Newcastle upon Tyne in January 1951, entitled " Combustion Problems of the Gas Turbine ". Printed by E. & F. N. Spon, Ltd., London, 1951.

engine could no longer be accelerated up to full power. Low pressure and low temperature were the cause. Today this danger has been removed by better mixture formation and reliable flame control.

Eddies : The so-called " velocity of flame propagation ", which in mixtures at rest is only 2 to 8 m/sec—depending on the fuel and the air mixture ratio—reaches ten times this figure in the combustion chambers of modern engines because of the eddies in the flow. For this, however, a flame zone at the injection point, maintained by a relatively small quantity of air of high turbulence, is required. By the reversal of already ignited mixture particles, fresh mixture is heated up and ignited.

Velocity of flow : It is very important that the mean velocity of flow chosen should not be too high. With a mean final temperature of 2000°, velocities of roughly 30 m/sec before the entry of the mixing air are usual. Here it should be noted that an excessively sharp separation between combustion air and mixing air is not advisable, because of oscillations in the combustion chamber. The addition of mixing air to the hot gases helps largely to complete combustion—an effect which comes clearly to light if a combustion chamber is allowed to run without mixing air. In this case the flame is at least twice as long, and often three or four times. However, the velocity of the gases becomes too high, combustion efficiency drops, which can be explained by the fact that the chemical reaction takes a certain minimum time. This time will get longer locally the higher the speed is at which the reacting particles are propagated. If the zone of fresh air entry is reached too soon, premature cooling stops the reaction.

Ratio of mixing air to combustion air : Experiments, whose results are summarized in *fig. 6*, have shown how combustion efficiency, pressure drop and quality of mixture are affected by the relationship between primary and secondary air. By using separate leads it has been possible to vary the relative quantities of the two, with constant total air mass flow, and to measure pressure drops separately. The criterion used for the quality of the mixture was the difference between the maximum temperature and the mean temperature at the combustion chamber outlet. With an increase in the value of μ there is a slight rise in combustion efficiency, despite lack of combustion air (λ = constant). The temperature difference on the other hand increases and the mixture therefore deteriorates. Pressure drops for primary and secondary air vary according to the relative quantities of air. Finally, the *mixing length* (distance between entry of mixing air and combustion chamber outlet) is of great importance. The quality of the mixture becomes poorer the shorter the available time compared with the mixing distance (cf. *fig. 7*). It is recognized that a doubling in the mixing distance reduces the temperature differences to one third. Combustion efficiency and pressure drops, however, are not affected by the mixing distance.

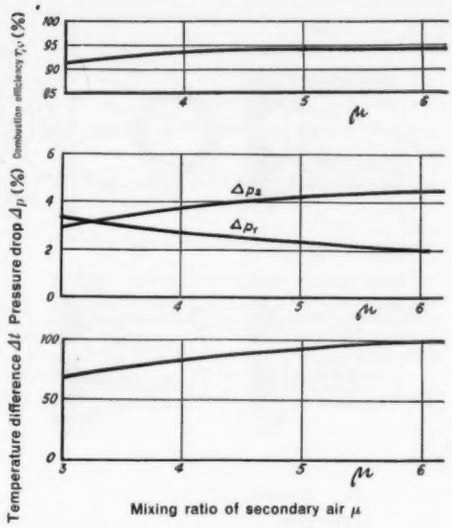


Fig. 6 : Combustion efficiency, primary air ratio, pressure drops of primary and secondary air and " quality of mixture " as a function of mixing ratio of secondary air with constant total air ratio ($\lambda = 4.5$). The quality of the mixture is measured by the difference between the maximum (measured) temperature and the mean temperature at the combusion chamber outlet.

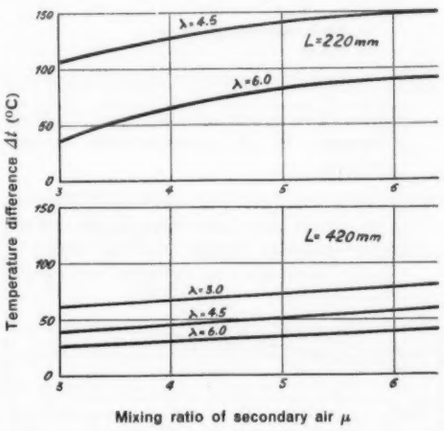


Fig. 7 : " Quality of mixture " (expressed as temperature difference) for two mixing distances L as a function of the mixing ratio of the secondary air (abscissa) and of the air ratio (parameter).

" Forming " the mixture in the combustion chamber

The general concept of " mixture formation " includes all the flow processes in both air and fuel. They begin with the injection of the fuel and end with the completion of all relative motion, including damping of the fuel. First a brief review of the demands made on the injection system :—

The maximum fuel quantity (for full power near the ground) is determined, for a given air quantity, by the strength of the turbine blades. In aircraft engines the injection quantity falls as altitude increases. At 39,000 ft. it is only a third of its maximum at sea level.

The engine must also be controllable, which requires a reduction of up to half the fuel quantity *(fig. 8)*. So that regulating can be done *quickly* the minimum fuel quantity must frequently be even smaller than would correspond to the state of equilibrium on which the regulation is based. Good combustion efficiency and stable combustion are essential if regulating processes are to be made as and when desired. In shaft engines the required regulating range is larger. Here it must often be possible to regulate for such small increases in temperature as 20 or 30°C.

If it is desired to alter the quantity of fuel injected in the ratio 1 : 10—not an excessive requirement—with a simplex jet, an alteration of 1 : 100 in the injection pressure is required. The permissible minimum pressure is determined by the minimum atomization conditions and the danger of the formation of steam bubbles. In general it is between 20 and 400 lbs/sq.in. This gives a maximum pressure, with simplex jets, of at least 2,000 lbs/sq.in. Such large pressure variations naturally affect the quality of the atomization and hence of the combustion efficiency, quite apart from the difficulties of producing the pressure.

Fuel injection nozzles must fill the following requirements :—

1. Good distribution and atomization of the fuel, regardless of quantity injected, so that optimum combustion efficiency can be obtained under all operating conditions.

2. Reliable ignition and stable combustion, even under unfavourable conditions.

3. Smallest possible pressure differences between minimum and maximum injection quantity, so as to keep maximum pressure low.

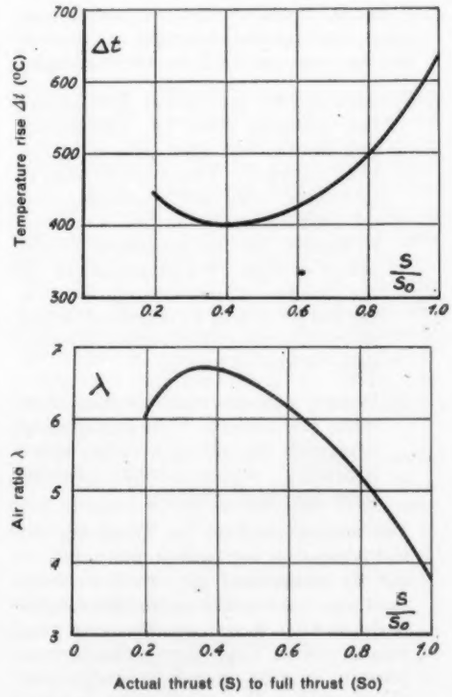


Fig. 8 : Temperature rise (Δt) and total air ratio (λ) as a function of the thrust of a jet engine. The curves apply to conditions of equilibrium, not to regulating processes.

4. No obstructions ; small, simple, easily accessible structure.

5. Very careful manufacturing ; maximum accuracy, best possible surface finish.

The movement of the air near the injection point plays an equally important part in the formation of the mixture. One of the most important objects of the test is therefore to tune injection apparatus and air movement to each other. With a little experience it is possible to recognize the adjustments required from the shape, colour and size of the flame, without making lengthy measurements.

Besides simple swirl nozzles other injection systems have been tried out and have today almost entirely ousted the former *(fig. 9)* :

— The *fuel is atomized* and blown into the combustion chamber. This system has certain advantages connected with mixture formation, and rapid, complete combustion, but inclines to suffer from the coking up of the atomizer. The only production model engine fitted with such a system is the British Armstrong-Siddeley " Mamba " propeller turbine, which has " walking-stick " up-stream injectors.

— On the other hand so-called *duplex burners* are very frequently used. They have two distinct inlets, one of which does not open until a pre-set pressure is reached and closes again when pressure falls below this level. The outlet section remains the same. A disadvantage, however, is that the angle of injection varies with the quantity injected. This type of burner is used in the majority of British and American engines, e.g., the Rolls-Royce " Nene ".

— *Constant regulable burners*, which can inject any desired quantity *at constant pressure*, are available in two versions :

a) Burners with mechanical flow regulation (piston or slide), i.e., with alteration of the fuel inlet section in the swirl chamber. This requires closest tolerances, very fine machining and careful filtering of the fuel, so as not to hamper the free movement of the piston or slide. A further danger—if the burner is over-heated—is that tar and pitch may be deposited, which will also hamper the freedom of movement of the regulator.

b) Return burners with constant flow inlets and outlets. Flow is controlled here with the aid of a valve, which limits the " return quantity " flowing from the swirl chamber.

— The energy required for atomizing the fuel is supplied not by high fuel pressures but by compressed air. Even ordinary swirl jets—which take up the fuel tangentially and let it out axially—give good results. With large flows, the forward pressure is great enough to ensure good atomization. If atomization becomes too poor as pressure falls it can be improved by blowing in air. Even low-grade fuels can thus be used. This injection system has proved satisfactory in test operation. It, of course, needs an air compressor.

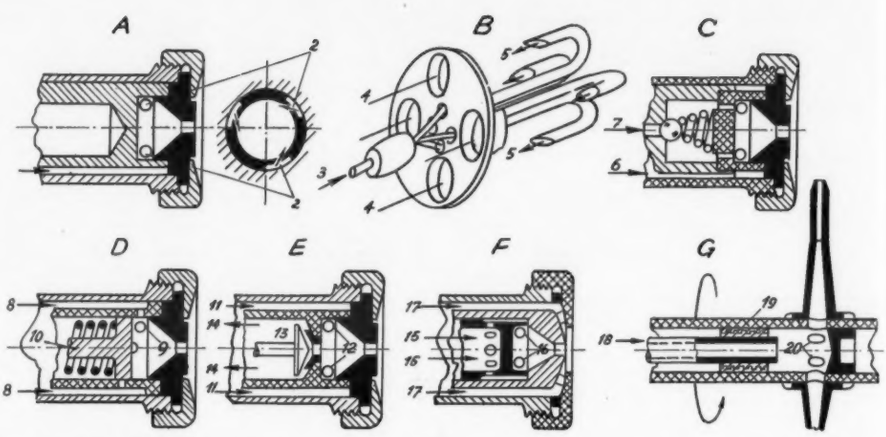


Fig. 9 : Some ignition systems

A : Simplex pressure jet
1. Fuel feed
2. Tangential drillings

B : Vaporization system (A.S. " Mamba ")
3. Fuel feed
4. Air
5. Fuel vapour/air mixture

C : Duplex pressure jet
6. Basic fuel quantity
7. Additional fuel quantity

D : Variable slot pressure jet
8. Fuel feed
9. Tangential drillings
10. Piston

E : Spill pressure jet with tip valve
11. Fuel feed
12. Tangential drillings
13. Tip valve
14. Spill

F : Air assisted pressure jet
15. Fuel feed
16. Tangential drillings
17. Compressed air

G : Rotary injection (in annular combustion chamber)
18. Fuel feed
19. Labyrinth
20. Radial drillings

— *Rotating injection* (Turboméca). Flow and atomization are here separated. The latter depends solely on the engine's r.p.m. The fuel's exit velocities are equal to those which otherwise are normally obtainable only with pressures of 5200 to 6400 lbs/sq. in. Thus even with low periphery speeds optimum atomization is ensured.

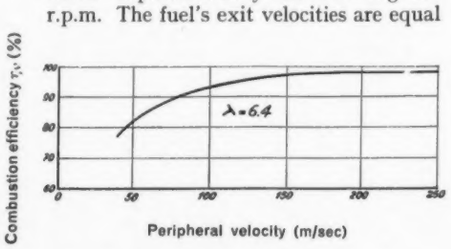


Fig. 10 : Combustion efficiency of a combustion chamber with " rotating injection jet " as a function of the peripheral velocity of the outlet aperture.

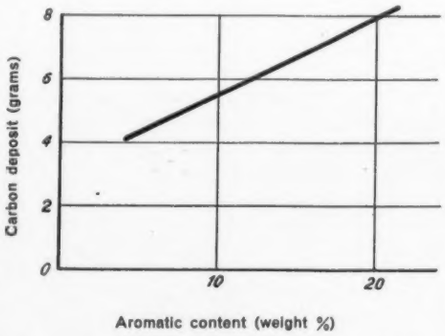


Fig. 11 : Carbon deposits in a combustion chamber after one hour's running with constant air and fuel throughput, as a function of the aromatic content of the fuel.

It should be noted that flow control in this system is by *overflow regulation at the fuel pump*. The fuel, already measured, enters a pipe which rotates with the turbine. The fuel flow is thus given the r.p.m. of the engine, is carried to the injection point by centrifugal force and enters the combustion chamber through radial drillings. These drillings are not metering orifices and are, therefore, never entirely filled with fuel and, as far as injection is concerned, may be of any size—thereby practically eliminating all danger of obstruction.

Fig. 10 shows the variation in combustion efficiency in the combustion chamber with rotating injection. Since all other data remain constant, the curve gives simply the influence of the mixture formation on combustion efficiency.

Fuels

Under favourable pressure and temperature conditions the usual hydrocarbons show very slight differences in performance and functioning, even when their structure and boiling points are different. But under even slightly difficult conditions a highly unsatisfactory characteristic comes clearly to light, namely a tendency to carbon deposits in the combustion chamber. *Williams* [5] measured the carbon deposits in an experimental

[5] M. C. G. Williams : " Fuels & Oils for Gas Turbines " in Shell Aviation News.

combustion chamber for fuels of varying aromatic content under otherwise similar conditions *(fig. 11)*. Such deposits do not inevitably mean a loss of efficiency but are always a sign of faulty or unstable combustion. They can be avoided by increasing the quantity of combustion air (in general and locally). Williams also found that the tendency to carbon deposits decreases with decreasing volatility of the fuel. For example kerosenes are better in this respect than naphthalenes and the latter better than aromatics.

If conditions are deteriorated by reducing pressure and temperature, the differences in behaviour between the various fuels increase. Silverstein [6] found a difference in combustion efficiency of up to 20% between normal octane and iso-octane *(fig. 12)*. Except for their chemical structure the two fuels are closely related. Here, too, kerosenes were found to be the most suitable.

The following general demands are made on turbine fuels :

— Stable combustion under all operating conditions.
— Good ignition, even at low pressures and temperatures.
— High calorific value.
— Non-corrosive combustion products, i.e., such as do not attack the material of the combustion chamber or the turbine.
— High flash point.
— Good delivery properties (by means of pumps) at all temperatures.
— Low water solubility, to avoid formation of ice in the filters at low temperatures.
— Low freezing point ; widest possible boiling range.

These requirements apply primarily to aircraft fuels and are only met by high quality liquid hydrocarbons. Fixed installations and surface vehicles could use cheaper fuels, e.g., natural gas or stack gas, with lower qualities. Certain cheap liquid fuels are also suitable, though if they are to be used greater allowance must be made for them than hitherto in designing the engine. Pre-heating of the fuel, up to 150°C, is essential, but must be done in such a way that the fuel does not lose all its components that have low boiling points. The future of the gas turbine depends on the solution of the fuel problem. The aim must be to arrive at the *coal dust combustion chamber*, which is already well within the realm of the possible.

Ignition

Initial ignition of the mixture in the combustion chamber is as a rule by high voltage *electric spark* (spark plugs). There are various ignition systems in use today, but they are not always reliable. If ignition is delayed liquid fuel collects in the combustion chamber, ignites explosively and burns away with a long flame. Low temperatures render ignition more difficult—particularly at high altitudes, where there are also lower pressures and higher air velocities.

Ignition behaviour also depends on a number of other circumstances, in particular on atomization and mixture formation. Since only a relatively small quantity of the mixture is ignited at the beginning of combustion, the heat produced must be so great that it outweighs the losses (dissipation, radiation, diffusion). Volatile components in the fuel (better mixture formation) facilitate ignition. The choice of the correct position for the spark plug is equally important. Ignition must take place at a point of *low* air velocity so that the reaction centre is not blown away again by the air flow.

Wolfhard investigated the necessary ignition power for spark ignition, by altering the pressure, with constant ignition power, in a gas mixture enclosed in a glass flask until ignition commenced. He also found that ignition improves with increasing distance from the electrode, i.e., that a longer spark ignites better *(fig. 14)*. However, the results of his experiments represent ideal results not obtainable in practice, because the distribution of the fuel, being never absolutely regular, the movement of the air (flow velocity) in the combustion chamber and the use of more or less efficient atomization (instead of vaporization) make ignition considerably more difficult.

An interesting experiment in this connection is one into the effect of the mixture formation on ignition behaviour *(fig. 15)*. The experiment was made with a Bosch injection nozzle of 40° aperture and an aperture pressure of 600 lbs/sq. in. To make the mixture poorer the spring of the jet pin was removed. The curves show that with good atomization a low fuel concentration suffices for ignition, and that the ignition range is simultaneously enlarged.

To ensure reliable ignition even under unfavourable conditions ignition powers of 150 to 200 Watt are required. Such systems should preferably be *glow plugs* rather than spark plugs. The glow material may be one of the well-known resistance alloys or silicium carbide, which can withstand temperatures of 1500°C in continuous operation. The specific resistance of silicium carbide is about 700 times as great as that of the usual resistance alloys. Ignition experiments with a glow plug in the cold chamber showed satisfactory ignition down to –40°C for kerosene in spite of bad mixture formation (freezing point of fuel).

The glow temperatures required were determined by dropping various fuels on a glow element whose temperature was regulated in stages. The *limit temperature*, at which a drop falling on the element still ignites, increases with increasing molecular weight of the fuel. It is :

400°C for lubricating oil
600°C for gas oil
680 to 700°C for kerosene
710 to 730°C for petrol

If a spark igniter is used, however, petrol ignites better than kerosene.

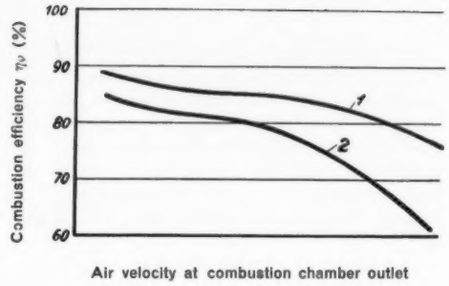


Fig. 12 : Combustion efficiency of an experimental combustion chamber run on octane and iso-octane with constant air ratio, as a function of the air velocity at the combustion chamber outlet.

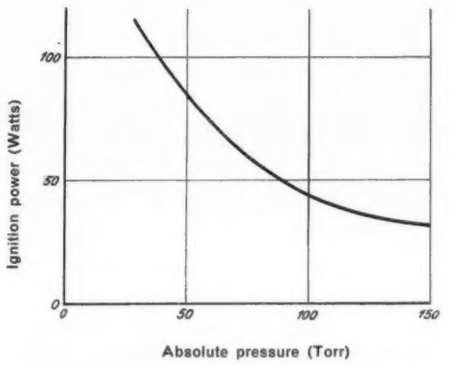


Fig. 13 : Ignition power required at lower ignition limit for spark ignition of a mixture of air and fuel vapour, as a function of the pressure. Distance from electrode was 0.9 mm; ignition occurred above the curve, but not below it.

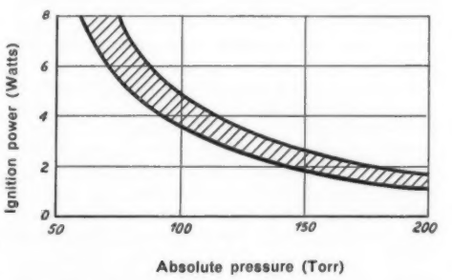


Fig. 14 : Ignition pressure required at lower ignition limit for spark ignition of a mixture of air and fuel vapour as a function of distance from the electrode. The " dispersion zone " is hatched.

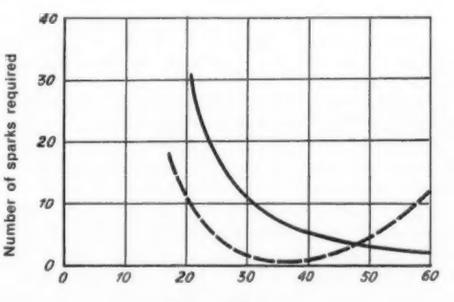


Fig. 15 : The number of sparks required for ignition in an experimental combustion chamber for good atomization (unbroken line) and bad atomization (broken line), as a function of the air-fuel ratio.

[6] Silverstein : " Research on Aircraft Propulsion Systems " in Journal of Aeronautical Sciences, April 1949.

Structural materials

Because of the high wall temperatures, the materials used for combustion chambers must be highly non-corrosive. Here use is made of weldable special steels which, besides a low carbon content (0.15 to 0.35 %) contain between 13 and 18 % chrome. In addition at least 8 % nickel must be added, to get *austenitic* texture. Otherwise internal stresses would arise through air hardening, e.g., after welding. Alloys of this kind (e.g., *V2A ED50* in Germany) are scale-resistant up to about 1000°C.

By raising the chrome and nickel content the temperature limit for scale-resistance can be raised. In pure chrome-nickel alloys (roughly 80 % nickel and 20 % chrome) it reaches about 1250°C. The alloy must of course have sufficient mechanical strength at working temperature, and this is provided by adding tungsten, molybdenum, titanium, etc.

In present-day combustion chamber production the wall temperatures can be so far controlled, e.g. by appropriate cooling pipes, that failures for this reason now rarely occur in practice. Structural elements are given room to expand, so as to avoid plastic deformations. Such failures in combustion chambers as occur nowadays are generally due to fatigue cracks produced by vibration. One combustion chamber, for example, showed only a few vibration cracks in neighbouring borings after a 1000-hour continuous run and was otherwise in excellent condition.

U.S. Airlines in 1951

New Records... and a Warning

The U.S. scheduled airlines passed several important milestones in American air transport history during 1951. Last year celebrated the 25th anniversary of scheduled air transportation in the United States. In 1951 the operating revenues of scheduled U.S. air carriers, including domestic trunk, local service, territorial and international operators, for the first time approached or passed the $1,000,000,000 mark. It was also the first year in which domestic trunk and local airline passenger miles exceeded the passenger miles travelled on the Pullman coaches of the American railways. Finally, 1951 may well have been the last year of the rapid post-war expansion of the airline industry. These facts are disclosed in the annual report on the state of the U.S. airline industry issued by the *Air Transport Association of America*.[1]

In his corresponding report for 1949, Vice-Admiral Emory Scott Land, President of the Transport Association, forecast new records for 1950, and in his survey of the following year he was able to point out that his prediction had been correct.[2] Although 1951 would have justified another optimistic forecast in 1950, Admiral Land refrained from making any prognostic, and the 1951 edition of the report once again confines itself to a sober compilation of facts illustrating the U.S. air transport industry's progress in the past year.

In addition to the highlights just mentioned, several outstanding features marked the evolution of the industry during the period under review. These included a *considerable growth in scheduled air coach or tourist services*, as a result of which nine domestic carriers were operating 64 daily coach flights between 34 cities at the end of the year. Furthermore, preparations had been completed for the introduction of tourist services on international routes, notably on the North Atlantic. 1951 also marked the introduction of " commutation " services between America's two largest traffic centres, New York and Chicago. The two cities are now connected by no less than 63 daily non-stop flights, which enable a businessman to leave either city in the morning, travel the 750 miles to the other city, transact business and return to the point of origin the same day.

Another significant aspect of the development of air transport in the U.S.A. during 1951 has been the *rapid expansion of local service operations*, which have brought the air age to 350 small towns, including a substantial number with populations as low as 3,000 people. In 1946, their first full year of operation, the local service lines flew 25,000 passengers over 6,812,000 passenger-miles. In 1951 they carried nearly 1,493,000 passengers over 294,436,000 passenger-miles. They now fly routes totalling 30,000 miles, from the Atlantic to the Pacific and from Canada to the Gulf of Mexico. There are 18 scheduled local service lines operating 130 aircraft and employing 3,800 people.

Speaking of the airline industry as a whole, comparative statistics (cf. Table I) show that in the *five-year period* since the end of the war the scheduled operators have *practically doubled their performance* in certain fields: total revenue passengers increased from 13,000,000 in 1946 to well over 24,000,000 in 1951 ; passenger miles from 7,000,000,000 to 13,000,000,000 ; mail ton-miles from 39,000,000 to 86,000,000. Express ton-miles were less than double—66,000,000 ton-miles in 1951 against 39,000,000 in 1946—but it should not be overlooked that the express peak was hit in 1950 with nearly 82,000,000 ton-miles. This drop is probably due to the fact that a proportion of express shipments has now shifted to the *air freight category, which has grown phenomenally* in the last five years—in fact, it has increased ten times in that period, from 14,800,000 ton-miles in 1946 to 146,500,000 ton-miles. This develop-

Table I : Traffic Statistics

(D = Domestic Trunk, Local and Territorial Airlines ; I = International Airlines)

Year		Rev. Pass.	Rev. Pass Miles (000)	Pass Load Factor %	Air Mail Ton-Miles	Express Ton-Miles	Freight Ton-Miles
1946 :	D**	12,213,445	5,947,956	78.81***	32,953,307	23,788,392	14,822,325
	I	1,041,283	1,100,741	70.85	6,141,461	15,090,468	60,037
		13,254,728	7,048,697		39,094,768	38,878,860	14,882,362
1950 :	D**	17,346,913	8,003,825	62.70***	47,008,947	37,279,035	114,072,045
	I	1,676,540	2,206,396	59.66	21,188,090	44,501,521	16,049,809
		19,023,453	10,210,221		68,197,037	81,780,556	130,121,854
1951* :	D**	22,602,979	10,580,531	70.32***	64,166,870	41,965,535	101,015,716
	I	2,030,766	2,552,329	60.88	22,130,497	24,400,868	45,547,733
		24,633,745	13,132,860		86,297,367	66,366,403	146,563,449

* Partially estimated
** Trunk, Local, Territorial
*** Domestic trunk only

[1] " Air Transport Facts and Figures ", 13th Edition, 1952.

[2] Cf. " Interavia Review ", No. 7, Volume VI, 1951, pp. 389-90: " U.S. Airlines Continue Their Progress ".

ment seems to be one of the two most significant single facts in U.S. air transport development in the past few years.

The second fact of great significance, mentioned at the beginning of this survey, was the continued " popularization " of air transportation through the expansion of the air coach services. It is probably these services which enabled the domestic scheduled airlines for the first time in 1951 to exceed the passenger mileage of the Pullman rail services. While *air passenger travel* rose by about 2,000 million (from 5,900 to 7,900 million) passenger-miles in the four years from 1946 to 1950, it *jumped by nearly 2,600 million to 10,500 million passenger-miles* during 1951 alone, as a result of which the airline share in the combined air/Pullman passenger mileage rose to 50.69 per cent (cf. Table II).

TABLE II

	Million Passenger-Miles 1946	1950	1951
Rail Pullman	19,801	9,338	10,226
Trunk and Local Airlines	5,910	7,956	10,511
Total	25,711	17,294	20,737
Airline Share	22.99%	46.00%	50.69%

The *earnings record* of the U.S. airline industry (Table III) also reflects the continued prosperity of the U.S. airlines. ATA's figures illustrate the operating revenues and profits of the U.S. domestic trunk, local service, territorial and international airlines during the *first nine months of 1951*. On the basis of revenues of $735,500,000 during that period, it can be estimated that total revenues for the year must have been very close to or over $1,000,000,000. This is borne out by figures, also contained in the ATA report, showing that the domestic trunk, local service and international lines alone — i.e., omitting territorial operators—had revenues of nearly $978,000,000 *during the full year*, as follows :

Domestic trunk lines	$658,522,906
Local service lines	35,275,232
International lines	284,172,128
	$977,970,266

Net profits of the airlines during the *first nine months* reached $51,000,000, and it is justifiable to assume that this figure rose to more than $60,000,000 by the end of the year. A figure of $60 million would represent six percent of the $1,000 million operating revenues, whereas the nine-month period, with revenues of $735 million and profits of $51 million, produced a profit rate of seven percent. However, this rate probably slowed down in the bad weather season towards the end of the year. But even six percent is a better return than that obtained in 1950, when a profit of $40 million on operating revenues of $816 million represented a return of just over 5 percent.

Operating expenses during 1951 rose roughly in proportion to the rise in traffic volume, i.e., they were about double the 1946 figure (see Table IV). This may appear like an anomaly, since the airlines' operating efficiency has improved enormously over the past five years, but here it should be remembered that while airline rates and fares have

TABLE III : Earnings Record

(D = Domestic Trunk, Local and Territorial Airlines ; I = International Airlines)

		Operating Revenues	Net Profit (After Taxes)
1946 :	D	$ 317,205,010	$ 5,732,544 *
	I	146,754,102	4,353,197 *
		463,959,112	10,085,741 *
1947 :	D	364,839,577	21,279,375 *
	I	209,009,511	5,124,630 *
		573,849,088	26,404,005 *
1948 :	D	434,295,383	5,478,776 *
	I	249,234,199	6,365,492
		683,529,582	886,716
1949 :	D	486,033,846	11,947,776
	I	274,154,538	7,454,189
		760,188,384	19,401,965
1950 :	D	556,366,449	30,246,060
	I	260,131,412	10,025,242
		816,497,861	40,271,302
1951** :	D	520,891,113	38,086,000
	I	214,672,630	12,910,000
		735,563,743	50,996,000

* Loss
** First Nine Months

remained virtually stationary or have declined in some cases, costs of equipment, materials and labour have climbed unceasingly during the same period. Hence, the operating expenses do not reflect the higher operating efficiency of the industry.

TABLE IV : Operating Expenses

(D = Domestic Trunk and Local Airlines ; I = International Airlines)

1946 :	D	$ 319,181,909
	I	139,842,846
		459,024,755
1950 :	D	489,587,226
	I	248,323,072
		737,910,298
1951 * :	D	593,845,638
	I	266,855,234
		860,700,872

* Estimated.

ATA's report stresses numerous other factors contributing to the favourable development. Proudly it points to the industry's *safety record* during 1951, a year which registered 12,464 daily take-offs and landings : the percentage of fatal crashes in total daily operations was roughly 1/10,000th of one percent. Combined domestic and international carriers achieved a record of only 1.3 fatalities per 100,000,000 passenger-miles (in comparison, railroad passenger trains had 0.41 fatalities for the same passenger mileage in 1951 ; passenger automobiles and taxicabs had 2.2 in 1950—figures for 1951 are not yet available).

At the end of 1951 the *scheduled air fleet* of the U.S. airlines numbered 1,165, against 1,145 at the end of 1950. However, some of this equipment consisted of larger, faster, more modern types, permitting the operators to obtain vastly better results. Of the total, 821 (802) were used by the domestic trunk lines, 130 (129) by the local service airlines (mostly DC-3s), 21 (21) by the territorial operators and 193 (193) by the international lines. Five-hundred were four-engined types. At the time of Pearl Harbour, the U.S. commercial air fleet consisted of 359 twin-engined transports and 27 flying-boats with a total of 6,734 seats. Today's scheduled fleet has 41,318 seats—which can be of decisive importance in an emergency.

*

ATA's report for 1951 shows once again that the U.S. airline industry has reached full maturity. For how long it will be able to operate as profitably as at present is another question, and in the past few weeks a number of *warning voices have been raised to awaken top airline executives from any state of somnolent optimism in which they may be indulging*. One pointer to the fact that the airlines may not continue their impetuous forward rush during 1952 came at the beginning of the year when airline stocks began to decline slightly on the New York Stock Exchange in the early part of January. This sensitivity of the market was justified a few months later : in May Trans-World Airlines announced a *net loss* of $552,923 for the first quarter of 1952, compared with a net profit of $151,287 for the same period of 1951 ; another of the U.S " Big Five ", Eastern Air Lines, reported that its *first-quarter profit for 1952 was down* to $963,886 from $2,262,719 for the first three months of 1951.

The clearest warning was sounded last February by Oswald Ryan, Vice-Chairman of the Civil Aeronautics Board. Despite the largest revenues in its history, he said, the U.S. airline industry was facing ominous clouds on the horizon. Increasing operating and procurement costs were outstripping the growth in business volume. New equipment now being delivered would create new capacity which could be utilized only by an estimated increase of $400,000,000 in annual revenue. This meant that the U.S airlines must show an increase in revenue of about $1,000,000 daily by the end of 1952.

Will the industry be able to produce such an increase ? The question is difficult to answer, especially in the face of statements like that made by American Airlines in its annual report for 1951, which says that " with the slower rate in traffic increase, anticipated increases in costs must be covered by an upward revision of fares and rates ".

All this goes to show that while the airline industry has become an indispensable component of the national economy operations-wise as a public utility, its earning capacity still suffers, in the eyes of potential investors, from an instability governed by the boom or recession tendencies of the same national economy.

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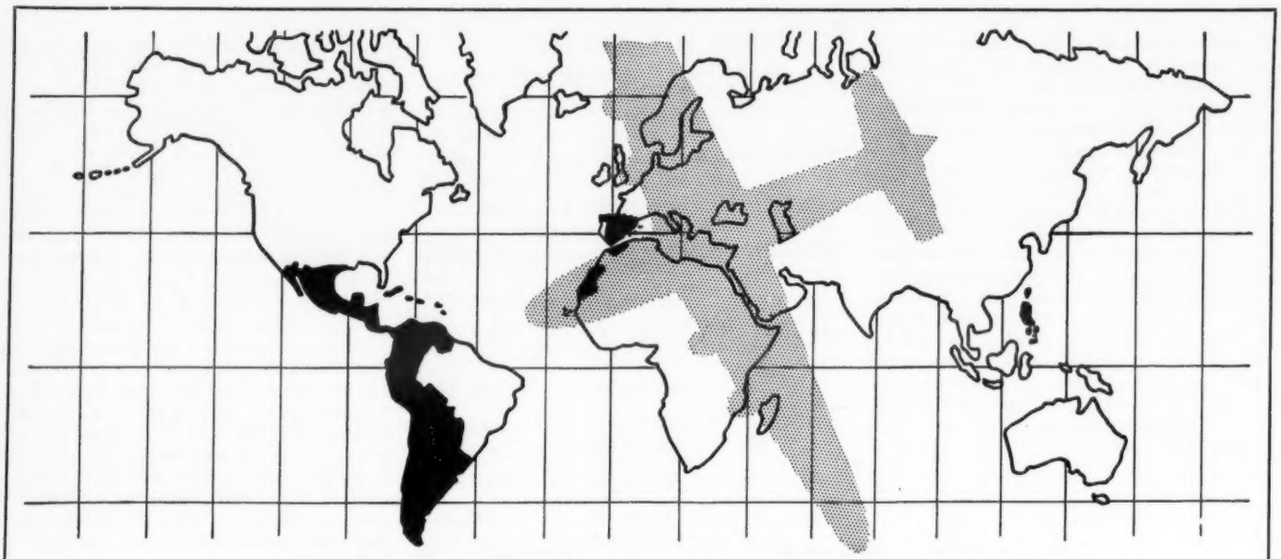

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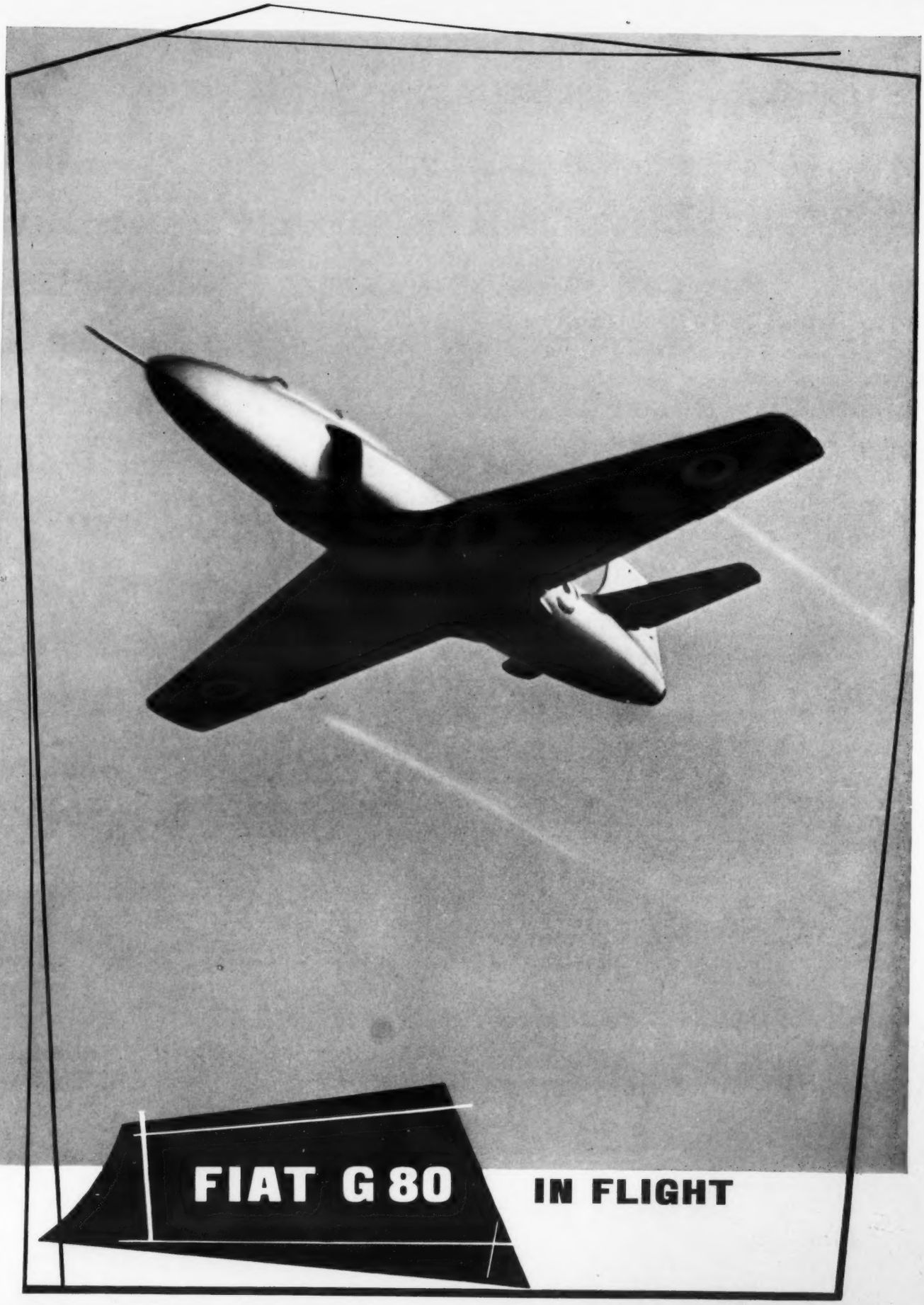

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